NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

COST ESTIMATION OF
ARCHITECT & ENGINEER CONTRACTS

by

Everette L. Herndon, Jr.

December 1981

Thesis Advisor: S. S. Liao

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UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Cost Estimation of Architect & Engineer Contracts		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; December 1981
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Everette L. Herndon, Jr.		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		12. REPORT DATE December 1981
		13. NUMBER OF PAGES 175
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Architect & Engineer Contracts
A&E Contracts
Construction Design Contracts
Brook's Bill
Acquisition Database
Cost Models
Cost Estimation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Architectural and Engineering firms are selected for government projects via a technical competition method with a fair and reasonable fee determined through negotiations. The criteria for what is fair and reasonable is the government estimate. There is a limited guidance available on the preparation of estimates for A&E contracts. Additionally, there is limited use of empirical information due to the lack of an organized database. This

research defined the cost estimation method as a decision process and supported that process with numerous analytical computations, statistical techniques, and regression cost models derived from a database comprised of previous A&E contract awards. This approach was effective in that estimates were generated which more closely represented negotiated fees.

Cost Estimation of Architect & Engineer Contracts

by

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Submitted in partial fulfillment of the
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MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
December 1981

ABSTRACT

Architectural and Engineering firms are selected for government projects via a technical competition method with a fair and reasonable fee determined through negotiations. The criteria for what is fair and reasonable is the government estimate. There is a limited guidance available on the preparation of estimates for A&E contracts. Additionally, there is limited use of empirical information due to the lack of an organized database. This research defined the cost estimation method as a decision process and supported that process with numerous analytical computations, statistical techniques, and regression cost models derived from a database comprised of previous A&E contract awards. This approach was effective in that estimates were generated which more closely represented negotiated fees.

TABLE OF CONTENTS

I. INTRODUCTION

A. GENERAL

The design of facilities for the Naval Shore Establishment is a significant function of the Civil Engineer Corps, the Naval Facilities Engineering Command, and the six Engineering Field Divisions. Design and design services result in the development of plans and specifications for a construction project. Plans and specifications are needed for all construction contracts including new construction, repair and alteration projects, and equipment installations. Quality in a set of plans and specifications is the product of professional engineering ability, innovative design capability, and knowledge of the state-of-the-art in construction techniques and materials. Additionally, plans and specifications must be complete, accurate, and explicit as they represent a major part of the legal documents for a construction contract.

Design services are obtained through two sources: (1) in-house government employee engineers and architects and (2) by contracting for these services with Architect & Engineer (A&E) firms. A&E contracting provides about 90% of the design work for the Navy. As such, A&E contracting is a major function throughout the Naval Facilities

Engineering Command and its subordinate Engineering Field Divisions (EFD).

A&E firms are selected by a procedure referred to as the "traditional selection method." This method provides for the selection of an A&E firm on criteria such as: demonstrated professional ability, capability to perform the work, and previous awards of government contracts. After the firm is selected, the fee is negotiated. The negotiation of A&E contracts and the traditional method of selection is provided for by P.L. 92-582, the Brook's Bill.

There has been much controversy over the Brook's Bill during the past ten years, however there have been no changes to that law. The major point of the opposition is that fee should be introduced in the selection process to encourage competition. Proponents argue the technical competition provided by the traditional method generates the factor of competition amongst A&E firms and promotes quality in design services. The Navy and Department of Defense support the contracting practices currently incorporated in the Brook's Bill.

A requirement of the Brook's Bill is that agency heads will negotiate a "fair and reasonable fee" for A&E compensation. The criteria for determining what is fair and reasonable is the government estimate. Accordingly, the development of an accurate government estimate is a significant event in the A&E contracting process.

B. PROBLEM STATEMENT

1. Developing the Government Estimate

Rear Admiral Iselin, former Commander, Naval Facilities Engineering Command [Ref. 1], in defense of the Brooks Act selection process, is quoted as follows:

> In contracting for A&E services, we are not buying a predetermined product; we are buying professional skill, creative talent, and a level of effort in the engineering and architectural fields.

A procurement of professional skill, creative talent and a level of effort are rather abstract commodities and difficult to quantify. The government Engineer-in-Charge (EIC) is faced with this problem when developing an estimate for an A&E contract. The EIC must transform the perceived scope of the construction project into the requirements for design of that project. This ability or skill is developed by experience and there is limited definitive guidance on the subject.

2. Evaluation of the A&E Proposal

Additionally, the problem surfaces when the negotiation board is evaluating the A&E's fee proposal. If there is a wide range between the government estimate and the A&E's proposal, who is correct? The negotiation process can resolve differences or misunderstanding on the scope of the construction project, but differences of opinion for required design services can be difficult to resolve, such as determining appropriate quantities of design work. For

example, "How many hours does it really take to design a barracks?" Obviously the answer is dependent on many variables, and a range of answers could be considered acceptable. Comparing the A&E's proposal to the government estimate will aid in defining the limits of that range, but there is a lack of organized empirical information available to assist in resolving the differences.

3. An Acquisition Database

A potential source of information available to the EIC for developing estimates and evaluating proposals is the existing A&E contract files. Comparisons to similar A&E contracts may be beneficial in determining the number of drawings, labor hour requirements, cost of studies, etc. These contract files represent the "corporate memory" and reflect organizational behavior for functions such as A&E contract negotiations. However, A&E contract files are not organized into a database that allows information retrieval. This limits the benefits of the corporate memory to the individual EIC when researching the files for a particular type of construction project design. Even with EFD computer capability available, there is an underutilization of the resource in A&E fee estimation. [Ref. 2]

This lack of organized acquisition databases is a common characteristic of federal procurement agencies. The problems caused by this situation were discussed by Blandin and Bruno [Ref. 3] as a result of their research project in

cost model formulation. They concluded the article, "there is a definite need to improve the data collection and retention process in a fashion that will render analytically responsive results."

C. GENERAL HYPOTHESIS

1. Decision Process

It is the premise of this thesis research that the development of an estimate for an A&E contract can be considered a decision process. The decision process approach will define the inferences between the descriptive factors of the project and the requirements for design services. Additionally, the decision process approach will establish relationships between the various components of the fee itemization.

As discussed in Chapter 2, EICs use a combination of the detailed breakdown and cartooning methods for estimating. The decision process of these methods is presented in flow chart form in Figures 1 and 2.

2. Decision Support

With the decision process in flow charted form, the next step will be to support the process with an A&E contract database. Using the A&E contract files, the development of a well-structured, comprehensive, and consistent database will provide the empirical foundation for decision support. Information can be retrieved from the database or

THE FLOW-CHARTED DECISION PROCESS FOR DESIGN SERVICES
-SECTION A-

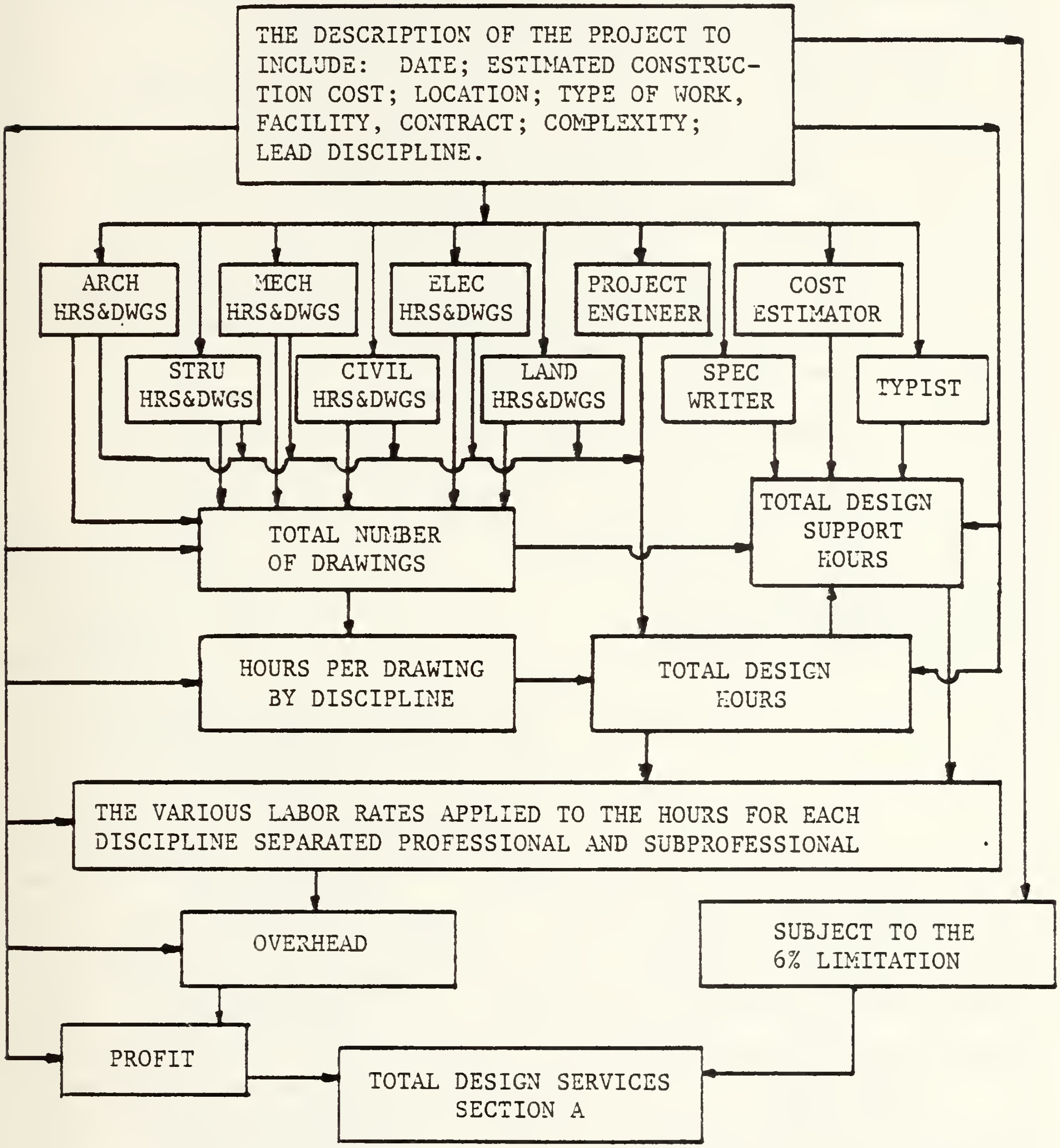

Figure 1

THE FLOW-CHARTED DECISION PROCESS FOR ENGINEERING SERVICES AND CONSTRUCTION CONTRACT SUPPORT SERVICES (CCSS) -SECTIONS B AND C-

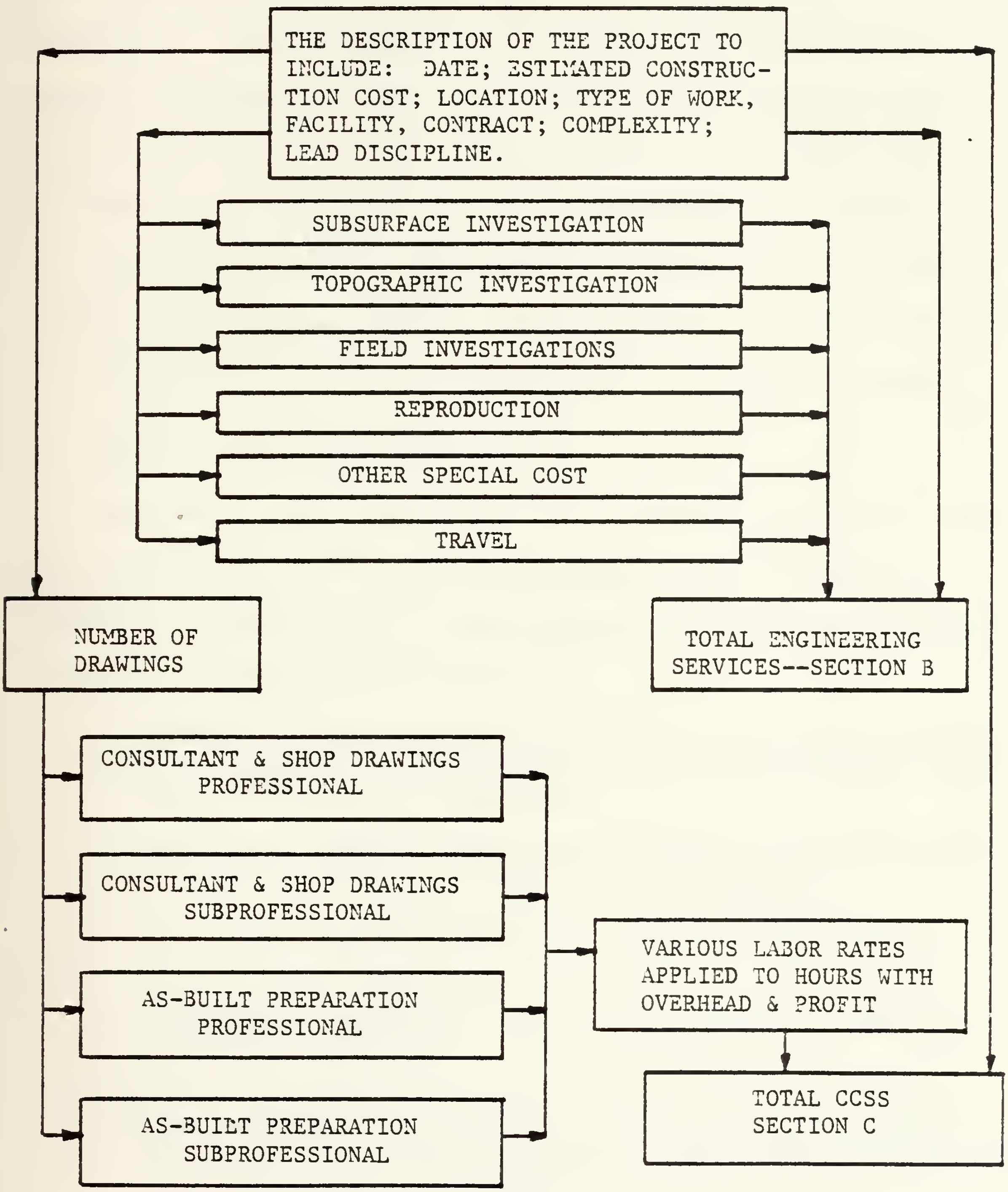

Figure 2

analytically derived to support each step of the decision process.

In addition to decision support, the development of the contract database will serve to support cost model formulation. The formulation of a cost model will focus on the general behavior of A&E cost from an objective and statistical perspective. The use of cost models for A&E fee estimation is limited due to the requirement to develop estimates in detail. However, cost models may be constructively used in the initial planning and/or budgeting stages of a design program or in determining a scoping estimate.

D. OBJECTIVES OF THE RESEARCH

Analysis of the cost estimation for A&E contracts with emphasis on the decision process and decision support approach accompanied by a well-structured database should achieve the following objectives:

1. Provide the government negotiator with strong empirical evidence and information as to the propriety of the A&E firm's fee proposal.

2. Serve as a pricing model for the EICs within an organization to develop consistent estimates.

3. Keep A&E contract pricing information up-to-date.

4. Develop cost trends for A&E contracts that can be compared to economic indicators to project cost on future A&E contracts.

5. Serve as guidelines to the newly hired or inexperienced government engineer in developing the ability to transform construction project scope into the required level of effort for design services.

6. Define the relationship between the various components of the fee itemization (number of drawings, hours per drawing, total man-hours, engineering support cost, ect.) for different scopes and types of construction projects.

E. METHODOLOGY

The research was conducted in four phases. The first phase involved constructing the necessary database. The data was collected from the Contracts Division of Western Division, Naval Facilities Engineering Command, San Bruno, California and included 300 A&E contracts negotiated over a thirty month period.

The second phase included performing numerous analytical computations to support the decision processes of A&E cost estimation. For each computation, a sample size, average, and standard deviation was computed. The computations were first performed on the complete database, then on different groupings of contracts. The groupings were based on eight factors which define and describe the A&E contract and the related construction project. Statistical techniques such as confidence intervals, multiple contrasts, and difference of means were used to determine the significance of the descriptive factors on A&E contract cost.

Cost model formulation was the objective of the third phase. Multiple linear regression was used to develop a prediction model for total A&E fee compensation, as well as

significant sub-totals of the contract including total professional design hours and number of drawings.

The fourth phase of the research was to test the validity of the decision process approach. The test was conducted by applying the decision support system to several test cases. Each test case was an A&E contract negotiated after the time period covered by the database. The test involved developing the estimate from the project description, then comparing the estimate to the government estimate and then to the negotiated contract.

F. THESIS ORGANIZATION

Chapter II provides a background discussion of the Naval Facilities Engineering Command's Design Program and of the selection, negotiation, and award process for A&E contracts. Additionally, an overview of the debate and controversy concerning the Brook's Bill is presented as well as the Department of Defense and Navy position on the issue. The chapter is concluded with a discussion of construction design estimating methods, the requirements and limitations placed on the government estimate, and the components of an A&E fee itemization.

Chapter III describes the methodology of the thesis research. Specifically, the development and description of the database, the analytical computations and statistical

techniques performed, and the formulation of cost models are explained in significant detail.

Chapter IV presents the findings of these computations, techniques, and models in support of the decision process and decision support approach to A&E contract estimation.

Chapter 5 demonstrates an application of the decision process approach. Additionally, the results of three test cases are presented to show the effectiveness of the decision support methodology.

Chapter 6 concludes the thesis with a summary of the background discussion, objectives of the research, and results. Additionally, recommendations for future research are provided.

G. SUMMARY OF RESULTS

The decision process and decision support approach to A&E contract cost estimation was effective. The objectives of this approach were achieved in that estimates which more accurately predicted the negotiated contract cost were derived. Additionally, a greater level of confidence in the accuracy of the estimate is achieved by having the support of a database of empirical information.

II. BACKGROUND

A. ARCHITECT & ENGINEER CONTRACTS

1. Naval Facilities Engineering Command Design Program

Among the many responsibilities of the Naval Facilities Engineering Command (NAVFACENGCOM) are those of designing and constructing Navy and Marine Corps facilities at the worldwide shore installations. The spectrum includes operational, training, production, storage, medical, administrative, and troop facilities; family housing; and utilities.

The total annual design and construction cost for the Navy Military Construction Program reached $752 million in 1979. NAVFACENGCOM also manages $50 - $100 million in Air Force and Defense Agency construction projects annually. Design and construction are administered through six Engineering Field Divisions (EFD) which divide the U.S. and the overseas locations into regional areas. (The six EFDs are listed in Appendix A.)

Two principal objectives dictate the design management process--first, that sound and reliable cost estimates are presented in the annual construction request to the Congress; and secondly, that award of construction contracts for quality engineered facilities are promptly enacted once authorizations and appropriations are enacted.

Planning and design funds are budgeted at a little less than six percent of the estimated cost of the planned construction program, with the bulk of the design effort being done by architect/engineer (A&E) firms under contract. [Ref. 4]

In addition to the design and planning of the Military Construction Program (MILCON), the bulk of design work for maintenance, repair and alteration construction projects funded through the Operations and Maintenance, Navy (O&M, N) appropriation is accomplished under contract with A&E firms. These A&E contracts are awarded at the EFD and local activity level.

Approximately 90% of all design work for the Navy is done by A&E firms. The scope of the design effort is quantified as follows [Refs. 5 and 6]:

Fiscal Year	Obligated for MILCON Design*	Total Value of All A&E Contracts	No. of A&E Firms with Contracts
76	$46,899,000	$ 67,500,000	947
77	59,195,000	72,500,000	1069
78	61,297,000	100,200,000	1378
79	53,941,000	91,600,000	1418
80	61,123,000	92,200,000	1355

2. Purpose

A&E contracts can be awarded for many different purposes related to the design and construction of a project. The scope of an A&E contract can involve any or all of the following items of work:

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*Figure includes both A&E contracts and in-house design effort.

1. Investigations to determine feasibility of proposed projects.

2. Other preliminary investigations and studies, with accompanying analyses, cost estimates, and reports.

3. Collection of design data such as topographic surveys, characteristics of subsurface materials, traffic census, origin and destination studies, manufacturing processes and related information.

4. Investigation of existing conditions where alterations are involved.

5. Preparation of construction contract plans, specifications and final cost estimates.

6. Assist with interpretation of plans and specifications during construction.

7. Check shop drawings submitted by the construction contractor.

8. Resident engineering service during construction.

9. Inspection of completed construction, supervision of performance tests, and related items to determine conformance with plans and specifications.

10. Preparation of "as-built" drawings for record.

11. Consultation and other related technical and professional services. [Ref. 7]

Contracts with A&E firms normally provide two options or phases, which are awarded sequentially. The initial award is for the conceptual work of identifying feasible technical alternatives and then developing the initial design for the most advantageous, cost-effective choice. This effort is referred to as the "35 percent design." When the A&E completes this stage of design and has submitted it for review and approval, a second option for the final design is made. The design effort can be stopped at the 35 percent

stage if necessary, which does not happen often. However, in those instances when a project must be deferred or the requirement for it no longer exists, limited design funds can be saved by termination at the 35 percent stage. This procedure also affords the opportunity to engage another A&E when the 35 percent design is considered unsatisfactory. [Ref. 8]

3. Authority

A&E contracts are awarded through a negotiated procurement process. In general terms, this authority is provided by 10 U.S.C. 2304.(a), subparagraphs (4) and (17) as follows:

> Purchases of and contracts for property or services covered by this chapter shall be made by formal advertising in all cases in which the use of such method is feasible and practicable under the existing conditions and circumstances. If use of such method is not feasible and practicable, the head of an agency, subject to the requirements for determinations and findings in section 2310, may negotiate such a purchase or contract if . . . (4) the purchase or contract is for personal or professional services; . . . (17) negotiation of the purchase or contract is otherwise authorized by law.

In the case of procurements for A&E services, subparagraph (17) of 10 U.S.C. 2304.(a) applies as 10 U.S.C. 7212 provides for the employment of outside architects and engineers as follows:

> Whenever the Secretary of the Navy believes that the existing facilities of the Department of the Navy are inadequate and he considers it advantageous to National defense, he may employ, by contract or otherwise, without advertising and without reference to sections 305, 3324, 5101-5115, 5331-5338, 5341, 5342 and 7154 of title 5, architectural or engineering corporations, or firms, or

individual architects or engineers, to produce designs, plans, drawings, and specifications for the accomplishment of any Naval public works or utilities project or for the construction of any vessel or aircraft, or part thereof.

More specific authority concerning negotiated procurements for A&E services is cited in 40 U.S.C. 542 and Public Law 92-582 as follows:

> The Congress hereby declares it to be the policy of the Federal Government to publicly announce all requirements for architectural and engineering services, and to negotiate contracts for architectural and engineering services on the basis of demonstrated competence and qualification for the type of professional services required at fair and reasonable prices.

4. The Negotiated Architect and Engineer Contract Process

Construction projects inevitably begin with the inception of an idea. After authority has been received to award a contract for the construction, repair, and/or maintenance of a facility and the funds have been appropriated, the original idea is expanded into a construction design.

There are essentially two methods of obtaining a design: the first is to use government personnel consisting of engineers and architects who are Civil Service employees; and the second is to contract with an A&E firm.

The determination of whether or not to use an A&E firm requires an investigation of a number of factors. Among those considered are the availability of in-house capability to meet the time requirements, and the type of project to be designed. Two important questions asked are: Is the proposed project located close in-house design capability, or

some distance away? Does the design division already have a balance of large and small jobs? If they do, the design division may want to consider to design by A&E contract. Another consideration may be the government's inability to contract within the fee limitations discussed later in this chapter. Once it is decided to contract for A&E services, an established NAVFACENGCOM procedure [Ref. 9] is followed for negotiating and awarding the contract.

Technical competition is a method employed to select a contractor where the qualifications of the contractor are of greater importance than the ultimate price of the contract or where the nature of the services to be procured make price competition impracticable. Technical competition is the method used for the award of A&E contracts, pursuant to Public Law 92-582. The A&E contracting procedure consists of four steps: (1) synopsis, (2) preselection, (3) selection, and (4) negotiation and award.

a. Synopsis

In accordance with Public Law 92-582, all A&E selections which are expected to result in a fee in excess of $10,000 must be synopsized in the <u>Commerce Business Daily</u>. A&E selections of lesser amount are to be publicized through appropriate notices at the contracting office and other places where they will give reasonable notice to A&E's in the area of the project. Each such synopsis or other publicizing must set forth the significant specific evaluation

factors to be applied in making the selection decision. The following items are examples of A&E selection evaluation criteria:

1. Specialized experience of the firm in the type of work required with a listing of specific skills required for the project;
2. Professional capacity of the firm to accomplish the contemplated work within the required time limits;
3. Professional qualifications of staff to be assigned to the project;
4. Innovative design capability;
5. Adequacy and qualification of subcontractors and consultants;
6. Past experience, if any, of the firm with respect to performance on Department of Defense contracts;
7. Cost control effectiveness;
8. Present workload;
9. Location of the firm in the general geographical area of the project, provided that there is an appropriate number of qualified firms therein for consideration;
10. Volume of work previously awarded to the firm by the Department of Defense.

At least 14 days must be allowed after publication of a synopsis in the Commerce Business Daily to permit firms wishing to be considered for selection to indicate that fact and file any necessary forms. The following wording must be utilized to conclude each synopsis issued by the EFD, or subordinate Officer in Charge of Construction (OICC):

> A&E firms which meet the requirements described in this announcement are invited to submit completed Standard Forms 254 (unless already on file) and 255, U.S. Government

Architect-Engineer Qualifications, to the office shown below. Firms responding to this announcement by ________ will be considered, and firms having a current SF 254 on file with this office can also be considered. See Note 62. This is not a request for a proposal.

The Defense Acquisition Regulations (DAR) provides that a Standard Form 254 shall be kept on file and updated periodically in contracting offices by A-E firms which wish to be considered for selections by that office. The Standard Form 254 is a general resume of the firm's experience. Requiring the filing of additional information for retention with a permanent resume, Standard Form 254, is not authorized. A firm which does not have a Standard Form 254 on file but wishes to be considered for a particular procurement may file that form along with the Standard Form 255 and/or other indication of interest.

The Standard Form 255 is a statement by a firm of its qualifications for a particular project for which selection is about to be made. The synopsis or other publicizing may require the submittal of a Standard Form 255 if the estimated fee of the A&E contract is under $25,000, but the synopsis must require the submittal of a Standard Form 255 by interested firms if the estimated fee is in excess of that amount.

b. Preselection

A slate (or panel) of qualified firms shall be compiled by a slate committee of at least three members (officer or civilian). The members shall be selected on the

basis of experience. Slate committees and selection boards are separate and distinct phases of operation. In order to achieve maximum objectivity in selecting A&E's, no person may serve on both the slate committee and the selection board for a project. The slate committee shall be provided with the proposed scope of work, government cost estimate, SF-254's and 255's, and responses to Commerce Business Daily announcements. The slate is not to be prepared from personal records of individual committee members. The slate committee shall also consider any experience data that is on file with the EFD, supporting data and information that may be obtained from other EFD's, the Corps of Engineers, NAVFACENGCOM, and other Government agencies, and information that may be requested from and submitted by prospective contractors. Much information will be provided on Standard Forms 254 and 255, giving specific information concerning the location of the firm, personnel of the firm, specialized experience, professional capabilities and capacity to undertake the work.

The slate committee shall evaluate each firm in light of the criteria set forth in the synopsis. Substantial efforts must be made to bring in new A&E firms (those who have never been awarded an A&E contract or have not recently been awarded an A&E contract) into the selection process. Each slate committee must assure that new firms are given every opportunity to participate on a fair and

equitable basis in the A&E program. It is firm DOD and NAVFACENGCOM policy that A&E contract selections shall be spread among all qualified firms including small and minority firms.

The slate committee shall submit a written report to the OICC. It shall state that the recommendations contained therein are based on an examination of contractor's brochures, performance records, and indicate the criteria used. The slate committee's report to the OICC shall list not only the names of firms recommended for final consideration but also, for information, the names of all other firms considered by the committee. The slate committee shall recommend at least four to six firms, and in the case of major projects of national interest, eight to ten names for general consideration and interview. So far as practicable, the firms to be considered shall be selected from the area where the work is located. On larger or specialized jobs beyond the capacity of local firms, they may be selected from voluntary joint ventures which generally include a firm from the area where the work is located. There are very few areas in the U.S. today where the A&E profession is not capably represented. Although primary consideration should be given to experience and satisfactory performance, effort shall be made to spread the work and to give consideration to new firms. Firms having awards of $100,000 or

more in the current or preceding calendar year normally will be excluded if other qualified firms are available.

An OICC may approve the slate as submitted, or, if not satisfied with the report of the slate committee, may return the slate to that committee or to a new slate committee with instructions for restudy and preparation of a new slate. An OICC may not add firms to slates or delete firms from slates. The convening of a new slate committee may be necessary when substantial time has elapsed, Government personnel have departed, or other good and sufficient reasons exist.

c. Selection

The approved slate shall be forwarded to the Selection Board, together with all of the brochures, performance records, and other data available for the firms on that slate. The Board shall interview the recommended firms with regard to establishing their technical qualifications, experience, organization, capacity, current workload, immediate availability, key individuals who will be placed on the work, and other relevant factors. In the event there is a possibility of follow-on work, interviews and selection bases should include the candidate firms' qualifications for the entirety of the work. There shall be no discussion, at the time of the interview, of the price to be paid for services. However, the general magnitude of the proposed contract may be indicated for the purpose of avoiding

misunderstandings. The Selection Board may not add firms to, or delete firms from, the slate.

If the Government estimate for the contract is less than $10,000, the selection may be made on the basis of prior interviews or the data on file, subject to telephone verification of the firm's interest, current work load, availability of qualified personnel and other relevant factors. Selection solely on the basis of Standard Form 254's and 255's is hazardous, in that a firm's circumstances may have changed since they were prepared.

If the Government estimate exceeds $10,000 or if the project is of more than routine difficulty, the selection shall be based on oral or written discussions with the recommended firms. Discussions shall be directed to the specific project under consideration and may be conducted by telephone (as hereinafter set forth) when considered appropriate. However, A&E contracts expected to exceed $50,000 in fees should be awarded on the basis of personal interviews by a Board of at least three members, each of whom shall attend the interviews. Telephone interviews are not to be used when A&E contracts are expected to exceed $50,000, except in urgent situations approved in advance by the EFD Commander.

As soon as possible after the interviews, the Board shall, in private session, discuss the qualifications of the firms interviewed. The Board members shall, by

secret written ballot, select the firm they consider best qualified to perform the particular project at the particular time required. The Board should also select a second and third firm in order of preference. The ballot shall not be signed and no attempt shall be made to ascertain how individual members voted. It is within the discretion of the Board to decide, before a ballot is taken, that a two-thirds or a three-fourths vote (or a simple majority) shall be required for selection. No representatives of the contractors or other private interests shall be permitted in the room during the Board's discussion of the qualifications of the firms that have been interviewed, and persons who are not members of the Board shall not be permitted in the room during balloting.

A Board Report, in the form of a written recommendation to the OICC, shall include an explanation of the reasoning on which the Board recommends the particular firm but shall not indicate how individual members of the Board voted. The OICC shall specify, in writing, his approval or disapproval. When an OICC approves and forwards to the Board for final consideration the slate of contractors, it must be considered that every firm on the slate is basically qualified to perform the work in question.

The contractor who is selected shall be advised by letter that the OICC wishes to receive a price proposal for the services in question with a view toward entering

into a contract if a satisfactory price agreement can be achieved. It should be clearly stated that this notice is not an award or a commitment by the Government. Suggestion that the contractor visit activities or incur other costs in preparation for the price discussions is desirable. However, it should be stated that the suggestion is made for the contractor's benefit and that any decision as to whether to comply is at his own discretion. The Government will not be responsible for the costs incurred.

d. Negotiation and Award

After receipt of the price proposal from the A&E firm, the negotiation board shall carefully review and compare it with the government estimate in order to determine whether or not there are any significant differences. If the contractor's proposal is equal or less than the government estimate, the amount involved is $25,000 or less, all elements of the proposal are in line with the estimate, and the negotiation board is fully satisfied that the contractor has a complete and full understanding of the work to be performed, award may be made without further negotiation.

If any element of the price proposal varies significantly with the government estimate, even though the total amount may be in accord with the government estimate, or if the amount involved is over $25,000, the negotiation board shall schedule a meeting with the contractor for the purpose of negotiating the contract price. Normally such

negotiations will first involve a discussion of the work to be performed in order to assure that there is no misunderstanding between the government and the contractor as to the nature and extent of the work. In this regard, discussions occasionally identify errors in the government estimate. When errors are found, the government estimate should be adjusted as may be appropriate. This adjustment may be made in the Board Report and need not be made in the estimate per se.

On completion of discussions of the scope of work, the parties should conduct a detailed review of the various price elements. Normally, if the overall price is in agreement this discussion will start with proposal items that are out of line with the government estimate. However, if there is a significant difference as to the total price, it is in the best interest of both parties to proceed with an item by item analysis to determine the reason and basis for the differences between the proposal and the government estimate.

During negotiations, figures in the government estimate may be disclosed to the extent deemed necessary in arriving at a fair and reasonable price. However, under no circumstances may the overall government estimate be disclosed.

For all negotiated procurements a Board report or memorandum of negotiation shall be prepared. This report

shall include as a minimum, the justification for the recommended price including any differences between the contractor's proposal and the government estimate and the method of resolution thereof and justification for any negotiations concerning time.

In the event that a price cannot be negotiated with the selected A-E firm, Section 904 of Public Law 92-582 provides instruction for continued negotiations as follows:

> The agency head shall negotiate a contract with the highest qualified firm for architectural and engineering services at compensation which the agency head determines is fair and reasonable to the Government. In making such determination, the agency head shall take into account the estimated value of the services to be rendered, the scope, complexity, and professional nature thereof.
>
> Should the agency head be unable to negotiate a satisfactory contract with the firm considered to be the most qualified, at a price he determines to be fair and reasonable to the Government, negotiations with that firm should be formally terminated. The agency head should then undertake negotiations with the second most qualified firm. Failing accord with the second most qualified, the agency head should terminate negotiations. The agency head should then undertake negotiations with the third most qualified firm.
>
> Should the agency head be unable to negotiate a satisfactory contract with any of the selected firms, he shall select additional firms in order of their competence and qualifications and continue negotiations in accordance with this section until an agreement is reached.

No negotiated contract or change order shall be awarded nor shall a contractor be authorized to proceed with work, pending award, until all of the reviews, approvals and clearances have been obtained. In addition, no contract or change order shall be awarded unless the OICC is in possession

of adequate funds to fully cover all of the work required to be performed by the contractor under the terms of the contract or change order. This does not require that the OICC hold funds adequate to cover options or other future contingencies which are not a mandatory requirement of the contract or change order as issued.

Subsequent to the award of an A-E contract, after required approvals have been obtained, information may be released identifying only the firm selected and the total amount of the award. The agreed to estimated construction cost of the facility to be designed shall not be divulged. In no instance shall other firms be given access or information concerning the price or technical information submitted by another offeror with the exception of revealing the price upon which award was made.

5. <u>Open-Ended Architect & Engineer Contracts</u>

The term "open end contract" refers to a special category of A&E contract wherein a firm is engaged to do the design work on a particular project with the stipulation that the firm will then be provided additional projects to design, up to a maximum total design fee, on an "as needed" basis. The advantage of this type of contract lies in the ability to award small design packages in a relatively short time frame.

To permit the greatest flexibility in obtaining design services wherever they may be needed, open end contracts

can be in effect in each of the major geographical areas of an EFD. To provide for further flexibility and to allow greater use of smaller specialized forms, contracts may be established for each of the primary design branches the EFD's design division.

OICC are authorized to assemble open-ended A&E projects required to be performed within a six month to one year period and synopsize these projects in a single synopsis in the Commerce Business Daily, with selection and award subject to:

1. No contract shall exceed $99,000 in total A&E compensation.

2. No single project shall exceed $40,000 in total compensation.

3. A specific project or projects must be in existence at the time of synopsizing, with completion of other projects of a similar nature known to be required within the reasonable future.

4. Selection must be based upon personal interviews of firms by the selection board.

5. The method of administration proposed herein is to award an A&E contract for certain basic work, with other work to be added by negotiated, fixed-price, lump-sum change orders during the life of the contract.

6. The initial selection board interviews and report should clearly describe the initial work and generally describe the additional work contemplated by the selection, with a total estimated fee for the particular contract and a showing of the general magnitude of the work for which the contractor was selected.

7. Meticulous and judicious care must be taken to spread A&E fee work so that several contractors are selected for work at any particular activity. For example, if total A&E fee compensation for a given one-year period is estimated at $100,000, then the work should be

planned in a manner to utilize at least three or four contracts.

8. The authority set forth herein is in no way to be considered permission to contract for personal services, engineering on an hourly basis, or the hiring of engineers in contravention of personal services prohibitions.

There are no limits other than the $40,000 on the amount of the initial award. However, it is obvious that too large an initial contract seriously limits the amount of subsequent awards. In connection with the $40,000 limit, incrementation of a design is not allowed, i.e., it is illegal to award the 35 percent or some other part of the design in one change order and then award the final design in a separate change order to avoid the limitation. All services for any one design must be included in a single change order. An open end contract cannot be initiated unless it is based on a firm requirement for a particular design. [Ref. 10]

B. OPPOSITION TO PUBLIC LAW 92-582

1. General

The selection of A&Es using the technical competition method is authorized by Public Law 92-582, commonly referred to as the "Brooks Acts" for its proponent, Jacks Brooks, Chairman of the House Government Operations Committee. The law was enacted in October 1972 as an attempt to strengthen competition in the awards of design contracts to Architect-Engineer firms for Federal projects.

Public Law 92-582 added two requirements to the traditional method used by Federal agencies to select architect-engineer firms. These were to (1) publicly announce proposed projects and (2) have a discussion with at least three firms prior to selecting a firm with whom to negotiate a price. These two requirements were incorporated in the technical competition selection method.

The architect and engineer societies long have endorsed a procedure, known as the traditional method for selecting architect-engineer firms for design contracts. Under this procedure fee or price is not discussed prior to selecting a firm with whom to negotiate a contract. The societies oppose the consideration of fee in the selection process. They fear that this would result in price competition and deterioration of the quality of services rendered. [ref. 11]

2. <u>Lack of Fee Consideration</u>

a. General Accounting Office

The lack of fee consideration in the selection of an A&E firm has been highly controversial and the subject of debate. The current controversy began in 1965, when the General Accounting Office (GAO), in a report to Congress, raised the issue that a fee paid by NASA for the design of a Nevada facility had exceeded the statutory 6% limitation imposed by law. As a result of a government study authorized

by Congress, GAO recommended price competition for the selection of consultants. [Ref. 12]

Specifically, the GAO report in April 1967, entitled "Government-Wide Review of the Administration of Certain Statutory and Regulatory Requirements Relating to Architect/Engineer Fees" suggested to the Congress that A&E services be acquired through competitive negotiation techniques prescribed in Public Law 87-653.

> Public Law 87-653 (section 2304 (g) of Title 10 U.S.C.) and the Federal Procurement Regulations require with certain exceptions, that, in all negotiated procurements in excess of $2,500,* proposals be solicited from the maximum number of qualified sources consistent with the nature and requirements of the supplies or services to be rendered and that written or oral discussions be conducted with all responsible offerors who submit proposals within a competitive range, price, and other factors considered.

However, in response to the 1967 report, representatives of professional societies and DOD stated that the legislative history of Public Law 87-653 constituted substantial ground for concluding that the competitive negotiation requirements of the law were not intended to apply to A&E services. In this regard, GAO felt it important that the Congress clarify its intent as to whether the competitive negotiation requirements of Public Law 87-653 were applicable to A&E procurements. [Ref. 13]

The GAO was asked by Congress for its views on the proposed Public Law 92-582 in 1972. At that time GAO

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*The $2,500 limitation has since been raised to $10,000.

recommended witholding congressional action until the Commission on Government Procurements had an opportunity to report its recommendations to the Congress, but stated the belief that the concept of competitive negotiations could be as successfully applied to the procurement of A&E services as it has been to similar professional services without degrading the quality of service. The Congress, however, decided to enact the legislation which established the Brook Laws with the technical competition selection method.

In its December 1972 report, the Commission on Government Procurement gave majority and minority opinions on procuring A&E services. The majority recommended that:

> Procurement of A&E services, so far as practicable, be through competitive negotiation techniques and based on the premise that selection be made primarily on technical competence and merits of end products, including cost, and that the fee to be charged would not be the dominant factor in contracting for professional services.

The Commission minority recommended that procurement of A&E services be based on the process as indicated in Public Law 92-582. They maintained that methods recommended by the majority would be less effective in obtaining the best professional services than the traditional selection method and might result in the A&Es fee estimate becoming the "primary factor for selection purposes." [Ref. 14]

Since the issuance of the Commission's report, several bills have been introduced in the Congress supporting competitive negotiation techniques for selecting

A&Es. Also, as alleged A&E award abuses have become widely publicized, several professional organizations have studied A&E selection procedures and have suggested improvements which could be made to alleviate such abuses. These studies stressed that selection procedures paralleling Public Law 92-582 provide sufficient competition and enable clients to obtain the best end product. This is in accord with positions previously taken by the professional organizations. Their recommendations encouraged States to enact legislation paralleling Public Law 92-582 as well as encourage State licensing boards to adopt codes of ethics and responsibility for disciplinary actions (where possible through legislation) against violators. [Ref. 15]

The GAO again attacked the Brooks Law in 1976 [Ref. 16] for the lack of fee consideration in the selection process. The basis for the report is cited as follows:

> The competition--or lack thereof--required by the Federal Government in procuring A&E services differs from that required for most other procurements. This has been the topic of considerable debate and interest for many years. Aroused public and congressional concern, plus the belief that contracting procedures can be strengthened and competition improved, caused us to evaluate the manner in which the Federal Government procured these services.

The conclusion of the GAO report recommended the Congress repeal Public Law 92-582 or provide for its amendment to require competitive negotiations. <u>Engineering-News Record</u> [Ref. 17] summarized the report as follows:

> In a far-reaching and highly critical report on federal architect-engineer selection practices, the General

Accounting Office (GAO) has called for repeal of the Brooks law and greater emphasis on fees in choosing construction designers.

The report signals little changes in GAO's historic view of greater price competition in A&E procurement, but it is significant in that it details objections to the traditional non-fee selection method by government agencies and strongly urges Congress to overhaul the system.

The report is seen as the opening shot in a battle to revamp federal A&E selection methods when Congress reconvenes next year. The Department of Justice and the Office of Management and Budget's Office of Federal Procurement Policy also favor major A&E selection changes.

The GAO further concluded that the Department of Defense and General Services Administration have generally complied with the two changes that PL 92-582 made to the traditional method of A&E selection, i.e., (1) the public announcement provision, and (2) the discussion provision. However, the GAO is of the opinion "that the law has not brought about any significant change in the competition among A&Es for Federal projects." [Ref. 18]

b. Professional Codes of Ethics

Prior to 1972, the architect and engineer industry, in their Code of Ethics, forbade their members from submitting prices with their offers for comparison with prices submitted by other architects and engineers on the same project. This practice is inherent in the traditional method of selecting A&Es and is prescribed in the Brooks Law. Andrews [Ref. 19] therefore concludes that the A&E industry is able thereby to fix prices for its services and prevent its members from offering lower prices in a truly

competitive market. Additionally, he states that a government contracting officer who is faced with prices fixed by the industry is reluctant to give up the best qualified firm if he will be negotiating with the second or third best qualified at the same prices.

The United States Department of Justice (DOJ) began to question the learned professional's exemption from the Sherman Anti-Trust Act. On May 1, 1972, DOJ filed a complaint against the American Society of Civil Engineers (ASCE) for violation of the Sherman Act with respect to restraint of interstate trade. Article 3 of their Code of Ethics, the item that brought the DOJ suit against ASCE, declared it unprofessional to invite or submit priced proposals under conditions that constituted price competition. ASCE, deciding it was wiser to comply than fight, signed a Consent Decree with the DOJ and removed the offensive portion of the Article from the Code of Ethics. The American Institute of Architects also found it easier to comply, but the National Society of Professional Engineers (NSPE) decided to fight the DOJ suit. After nearly 5-1/2 years and many dollars, the United States Supreme Court ruled against NSPE on April 25, 1978. [Ref. 20]

Even though the modern trend in the courts is apparently to strike down long-standing ethical standards as in the NSPE case, the decision did not embrace competitive bidding or endorse the concept. Rather, as discussed by

Lunch [Ref. 21], the Court noted that ". . . competitive bidding for engineering projects may be inherently imprecise and incapable of taking into account all the variables which will be involved in the actual performance of the project." The Court recognized that an owner might conclude that his interest in quality outweighs the advantage of achieving cost savings by pitting one competitor against another. Finally, the Court even recognized that NSPE had provided ample documentation for its thesis that competitive bidding might lead to defective results, but concluded that even with such documented reasoning, the ethical standard could not stand under a "per se" approach, thus rejecting the "rule of reason" rationale. Lunch concluded the article with the following:

> It seems to be difficult for antitrust authorities to recognize that there is indeed intense competition for engineering assignments, and always has been, and that such competition is mandated by the Federal Brooks Law and similar state laws governing A&E procurement. Unfortunately, they fail to understand that there is more to competition than price competition; that price competition has meaning only when the things being compared are equal, and that this can never be in the conception and formulation of an intellectual approach to a problem or need of a client for an engineering project.

c. Congressional Action

Congress has attempted various actions in an effort to introduce fee consideration in the selection of A&E firms. However, as pointed out by Andrews [Ref. 22], the efforts have not been coordinated with consistent legislative proposals.

The House investigative staff and members of the Subcommittee on Appropriations having jurisdiction of defense construction recommended accordingly that there be a test and evaluation of competitive pricing procedures for A&E services. However, Assistant General Counsel (Logistics) Trosch, in a written opinion, stated that the Department of Defense was limited by its Construction Authorization Act (Section 604, PL95-356) to a selection process that is "consistent with the presently established procedures, customs, and practice," as set forth in the Brooks Act. He concluded that a statutory provision specifically authorizing such a test of price comparison would have to be enacted by the Congress.

However, in November, 1978--in accordance with the instructions from the House Conference Committee--the U.S. Corps of Engineers began the implementation of a five million dollar test program for considering price as a factor in the selection of architect-engineers.

In January 1979, shortly after the test program was under way, its legality was questioned by a staff member of the Senate Armed Services Committee. On February 27, 1979 Senator Hart wrote Secretary of Defense Brown asking that further work on the test be suspended and noted that ". . . the test appears to violate Section 604, PL 95-356 which requires that A&E contracts be awarded in accordance with established procedures unless otherwise specifically

authorized by the Congress . . . ." The "established procedures" are those prescribed by the Brooks Act.

In response to a letter inquiry from Representative Jamie L. Whitten, Chairman of the Committee on Appropriations, dated August 1, 1979, the Comptroller General of the United States, in his reply of September 28, 1979 advised that because of the specific restriction of the Authorization Act, "The Congress must explicitly do so (authorize a pilot program) by specifically authorizing the test program by means of legislation." However, the Military Construction Authorization Act, 1980, contained the same Section 604 restriction on price competition for architect-engineer procurements as did the earlier Act, and the Military Construction Appropriation Act, 1980, contained no specific authorization for a test program.

3. <u>The Department of Defense Position</u>

a. General

The controversial issues over the A&E selection method for Federal projects has continued for several years. The basis of the controversy is P.L. 92-582, the Brooks Law, which establishes the "traditional" method of selecting A&E firms. There have been numerous proposals for changes to the law, but no congressional action has changed the Brooks Law since it was enacted in 1972.

Opponents of the Brooks Law argue the following major points:

1. The A&E industry can operate a price-fixing system for design contracts,

2. Favoritism and political corruption can be exercised with the current selection process,

3. There is no incentive for offering lower prices on part of the A&E industry,

4. Price comparison of different proposals is precluded.

Advocates of the Brooks Law, who oppose the introduction of fee consideration in the selection process, argue the following points:

1. The qualifications of the selected A&E are more important than price,

2. The consideration of fee will dominate the negotiation discussions,

3. A&Es will be forced to cut corners on the design effort to remain competitive, and as such, the quality of design, innovation, and creativity will be reduced,

4. The detailed development of fee and project proposals will increase design cost and delay project completions.

b. DOD Response to GAO

The Department of Defense in response [Ref. 28] to the GAO draft report titled "Review of Architect-Engineer Selection" commented on the GAO's proposed changes to or repeal of the Brooks Law to include price considerations in the selection of A&E. This letter defined the position of the DOD.

> The determination of the best method for selecting A&E's has been a controversial issue for many years. We concur in the statement of the report that Federal procedures should be a model for the Nation. The question to be examined therefore is what should be the objectives of a model selection system. In our view such a system should:

. Result in obtaining quality services for translating Government facility requirements into aesthetic and functional designs.

. Provide economical construction considering life cycle costs.

. Distribute the available work among all qualified firms including large, small, minority, and new firms.

. Provide safeguards to assure that public funds are being properly administered and that favoritism is not a factor in the selection process.

. Provide an administratively efficient system so that A&E's can be selected in a reasonable time with reasonable effort.

. Permit A&E's to seek and secure commissions without expending excessive time and resources and to receive reasonable fees on the basis of the required scope of work.

. Provide flexibility to permit variations in procedures to accomodate selections for projects varying in size and complexity.

. Assure that procedures and policies are being followed.

Unfortuantely, the objectives listed above are such that the achievement of one may work to the detriment of others. The selection of the most qualified firm may not result in obtaining a satisfactory distribution of work among firms. Attempting to select the best A&E for a particular job may not be compatible with the objective of avoiding the necessity for exercising the A&E profession in preparing unpaid proposals. Assuring that public funds are properly spent may result in an administratively inefficient system. These examples illustrate the interplay of the diverse factors which must be resolved in achieving a model system.

As discussed in the report, a so-called traditional method of selecting A&E's has evolved which is now covered in P.L. 92-582. This statute does not require consideration of fee in the selection process and the question of whether fee should or should not be considered has been a major issue. Another matter of contention concerns the amount of material that competing firms should furnish to provide a sound basis for evaluation.

It has been the position of DOD that P.L. 92-532, properly implemented, represents a reasonable balance among the conflicting objectives of a model A&E selection system. The rationale in support of this position are well stated in an exerpt from an Interagency Study on the Government Procurement Commission recommendations relating to A&E services as follows:

1. The prime objective in selecting an A&E is to obtain quality services for the translation of Government facility requirements into cost effective, functionally and aesthetically satisfying construction plans.

2. The introduction of price competition, regardless of the form utilized, does not enhance the selection of the best qualified firm.

3. The fees for A&E services are a small part of the total project cost and any potential difference in fees among A&Es would be inconsequential in comparison to the savings or other benefits which could be realized by the Government over the entire life of the project from the selection of the most highly qualified firm, or conversely, the potential monetary loss to the Government resulting from the selection of a less qualified firm.

4. The submission of meaningful proposed concepts and project cost proposals by competing A&E firms prior to selection would manifestly increase the expenditure of effort and costs by both the Government and competing firms. The development of design concepts runs 15 to 30% of normal fees. The routine request of 3 or more competitive concepts with project cost proposals would be very wasteful.

5. The resultant cost and effort required to prepare adequate concepts and project cost proposals, even for routine projects, would constitute a financial barrier to the participation of many firms, and most particularly small and newly formed firms, in competing for Federal A&E contracts.

6. The preparation by competing A&E firms of carefully conceived proposed concepts with realistic pricing for the construction end product, followed by Government evaluation, would necessarily require significant time, thereby unduly delaying the selection of the A&E and ultimately delaying the completion of the end product.

7. Primary dependence upon estimates and concepts supplied by competing firms would, in general, provide a less certain basis for selection of the best qualified A&E than is provided under current procedures through the use of the professional qualifications and record of actual performance of the interested firms.

8. The selection of an A&E should continue to be based upon Government technical evaluation of: the professional qualifications; experience; in-house capabilities and availabilities; caliber of consultants; demonstrated cost consciousness; and the comprehensive performance record of the competing A&E firms.

9. The depth and sophistication of inquiry, screening and evaluation in the selection process should be commensurate with the scope, complexity and urgency of the project and not arbitrarily bound by a rigid, time consuming and expensive selection procedure.

10. In order to assure the reasonableness of the A&E fee proposal, normal procedures require its comparison with an independent detailed Government fee estimate and, where fees exceed $100,000 preaward audits of A&E cost and pricing data with certification.

11. Undue emphasis on price competition might tempt A&Es to submit unreasonably low prices to promote favorable consideration, the the detriment of their ability to satisfactorily perform the necessary professional services.

12. The currently used (traditional) selection procedure, as expressed in P.L. 92-582 and DAR, should be retained since it provides a reasoned approach to the selection of A&E firms, in basic conformance with the procedures used in the non-Federal sector, and one which is also accepted as an equitable procedure by the A&E industry.

c. The Navy Position

The position of the Navy reinforces the DOD opinion. RADM D. G. ISELIN, former Commander of the Naval Facilities Engineering Command, presented the Navy position on the subject before the Military Construction Subcommittee

of the House Appropriation Committee [Ref. 24]. RADM Iselin is quoted as follows:

> I would like to address briefly the related topic of price competition in the procurement of architect-engineer services. The dialogue on this issue has been going on with varying degrees of intensity now for over ten years. I freely admit to having very strong convictions on this subject, convictions born of intimate personal involvement in this field for many years.
>
> In buying architect-engineer services, we are not buying a predetermined product. We are buying professional skill in the engineering and architectural fields, creative talent, and a level of effort. Until we go through a significant amount of dialogue with the A&E, which I will elaborate upon in a moment, there is no mutual understanding between the A&E and the government on exactly what the A&E will be required to do, and therefore no basis for him to make a realistic fee proposal.
>
> While we recognize that we are requesting substantial sums of money on an absolute basis each year, we feel it is important to view the design cost in the perspective of the total project cost over the term of its useful life span. If we take a typical bachelor enlisted quarters, for example, and examine the total cost over its estimated economic life of 25 years, we find that outfitting, operating, maintenance and repair costs represent 56 percent of the life cycle cost, construction costs represent 42 percent, and the design cost represents approximately 2 percent. This relatively modest cost notwithstanding, the A&E's design effort has critical influence on both the 42 percent for construction cost and especially the 56 percent for operations, maintenance, and repair. The design funds are 'front-end money' which has tremendous leverage on life cycle costs. Because of this leverage, it is vitally important that we get the highest possible technical quality in the design effort. In my professional opinion, any proposal which seeks to reap a near-term saving by reduction in cost, but which increased the risk of diminished technical quality of the design effort, is short-sighted in the extreme. We will live with the cost impacts of that diminished technical quality for the full economic life of the facility. This concern is the cornerstone of my opposition to price competition in the procurement of architect-engineer services.

There are, of course, varying forms of price competition, ranging from outright competitive bidding such as we use for construction contracting, to various approaches for considering fee as one of several factors. My concern is twofold: First, you cannot consider fee by itself--as I have indicated--quality of the design effort is paramount; secondly, I feel that once fee is introduced, it will tend to dominate. The A&E's fee proposal is an easily understood, concrete number which anyone can evaluate. The more important considerations of technical competence, design quality, and creativity are just the opposite--they are abstract, difficult to define, and hard to evaluate. I am afraid that fee will become the "easy way out" and that design quality will be degraded to our detriment over the long term.

Finally, in my judgment, the consideration of fee introduces a divergence between the interests of the government and those of the A&E. The government is interested in the highest quality design. Under price competition, the competitive pressures eventually induce the A&E to provide that amount of design effort which will just "get by," in order to reduce his fee proposal and thereby increase his chances of receiving the award. The pressures induced by fee competition, therefore, impel us toward the 'least common denominator': the least-cost A&E who, in order to cut costs, will reduce his design effort accordingly. These pressures run counter to the government's long-term objective for high quality design. What we need is an A&E who will consider the feasible design alternatives, evaluate the different candidate building systems to insure lowest life cycle cost, and provide us with the most cost effective project design for the long term. . . . We take great pride in the fact that there has been no hint of scandal in the Department of the Navy in our A&E contracting.

C. COST ESTIMATION OF ARCHITECT & ENGINEER CONTRACTS

1. The Government Estimate

The requirement for a detailed analysis of estimated costs for Architect-Engineer services is established by Defense Acquisition Regulations 18-108.2 which state:

Architect-Engineer Contracts: An independent Government estimate of the cost of Architect-Engineer services in the same detail as if the Government were submitting a proposal

> shall be prepared prior to the negotiation of each proposed contract or modification thereto, affecting price, expected to exceed $2,500 in amount. The cost breakdown figures in the Government estimate may not be disclosed prior to negotiations, but these cost breakdown figures may be revealed during negotiations to the extent deemed necessary for arriving at a fair and reasonable price, and provided, however, that the overall amount of the Government estimate is not disclosed. Any change in the Government estimate that is made during or subsequent to price negotiation shall be specifically, but succinctly, explained in the record of price negotiation.

Under the Brooks Act, the test of what is a "fair and reasonable" price for A&E services is the government estimate. As such, the government's estimate of the A&E fee will be designated FOR OFFICIAL USE ONLY and will not be divulged to the A&E. It will be used to determine the reasonableness and acceptability of the A&E proposal during subsequent pre-negotiation and negotiation meetings.

The estimate is based upon the scope of work which the government has decided to include in the final contract. As such, the negotiation process is used to determine contract requirements with the government estimate representing the quantification of project scope. RADM Iselin addressed this process in his "Statement of Planning and Design" to the Military Construction Subcommittee. [Ref. 25]

> We also prepare our own independent government estimate of the amount of A&E effort and the cost, in the first endeavor to insure that there is a mutual understanding of what the A&E is required to do. This dialogue is critical. The A&E through his questions may stimulate us to consider new and different technical approaches to meet our basic requirements. Through this dialogue, the project requirements are refined and agreed upon. Only after this mutual understanding has been achieved of what the A&E will be expected to do are we in position to consider price in its

proper perspective. Negotiations proceed with the objective of reaching agreement on a fair and reasonable price for the A&E effort. Through the negotiating process, differences between our estimate and the A&E's are identified, discussed and resolved. Usually there will be further refinements of project requirements during this exchange.

A&E contracts shall not be awarded in an amount in excess of the government estimate. If during the course of negotiations, it is determined that the government estimate is in error, or even in such instances as where the government estimate may not be in error, but the contractor's estimate represents a fair and reasonable amount for the work to be performed, the Board report for the negotiations shall indicate any variations or modifications to the government estimate which are appropriate and upon which it was determined that the contractor's proposal was fair and reasonable. [Ref. 26]

2. Methods of Estimating

a. A&E Industry Methods

There are several methods of developing design estimates being used in commercial practice. A discussion of current methods is presented below. [Ref. 27]

In the "phase and compensation" method, a given design fee is assumed, and the fee is broken down into a payment schedule according to each project phase. For example, 20 percent of the fee may be designated for the concept phase, 30 percent for preliminary design, 40 percent for working drawings, and 10 percent for bidding or

negotiations. The amount of money in each phase is then divided by the hourly rate normally charged, and a resulting number of man-hours for each phase is determined. The accuracy of this method relies on the experience and ability of the estimator to determine the required amount of design effort which is used to determine the design fee. An inexperienced estimator can overestimate or underestimate the fee by a considerable amount.

The "detailed breakdown" method is a technique of determining the number of engineering design man-hours based on a detailed analysis of the elements required broken down by specific discipline. This method provides fairly accurate estimates of the required man-hours, but it is quite time-consuming.

The "computed curve" method relies on historical data which relate the total number of design man-hours required for previous projects to the associated project costs. A curve is drawn to model this relationship, usually with project cost along the X-axis and total man-hours along the Y-axis. By knowing the estimated cost of a new project, the engineer can estimate the number of man-hours required to design a project by reading the man-hours where the estimated cost intersects the curve. Different curves can be established for different ranges of project cost. In addition, each project is evaluated by the engineer in terms of complexity and modularity. The results of this evaluation

may then cause the curve to be shifted within plus or minus three standard deviations from the mean represented by the initial curve. For example, if the project rated high in modularity and very low in complexity, the curve would be shifted down approximately three standard deviations; if low in modularity and high in complexity, the curve would be shifted up approximately three standard deviations before reading the number of required man-hours.

The "matrix" method also relies on historical project man-hour data related to cost and complexity to enable the engineer to estimate total project design man-hours. Cost ranges such as $0 - $25,000, $25,000 - $75,000, 75,000 - $150,000, and $150,000 - $400,000 are displayed vertically on the matrix. Complexity values are low, medium, and high and are displayed horizontally on the matrix. The cells of the matrix then contain the total number of man-hours for project design based on an estimated cost and complexity. The matrix method requires a large data base unique to each base and does not allow for the effects of other important design variables.

The "cartooning" method is a technique based on the estimated number of drawings which may be required, the amount of information or detail which should be contained on each sheet, and some knowledge of how many man-hours it will take to complete each sheet. To use this technique, an engineer must be experienced in all of the engineering

disciplines involved in a design or have experienced supervisors or senior engineers who can provide the necessary information. In addition, the engineer must have established a data base on man-hours per sheet of drawings.

b. The Navy Method

In accordance with the Defense Acquisition Regulations and NAVFAC P-68 policy to develop estimates in some detail as if the Government were submitting a proposal, the "detailed breakdown" or "detailed analysis method" is required for A&E contracts. Under the detailed analysis method, man-hour estimates must be made for each discipline of personnel services to be required by the A&E for accomplishment of design, engineering services and construction contract support services. Design projects normally involve professional and sub-professional personnel for the architectural, structural, mechanical, electrical, civil, cost engineering, and specifications disciplines. Estimated hourly rates are applied to the estimated number of man-hours for each discipline. Allowances are made for the A&E's overhead and profit to arrive at the total estimated fee, which is then used as the basis for negotiation with the selected architect-engineer. [Ref. 28]

The detailed breakdown method can be used in conjunction with the cartooning method. In practice, the combination of the two methods provides a greater analysis of detailed requirements and clearer presentation of project

scope. The engineer will determine the number of drawings within each engineering discipline to present the construction project, the cartooning method. Then the engineer can determine the man-hour requirements for each discipline based on the number of drawings, the details and complexity of each drawing, and then apply the labor overhead, and profit rates. This combination of methods is practiced among government engineers in developing cost estimates for A&E contracts. This method generates a government estimate in adequate detail to provide the A&E Negotiations Board with sufficient information to agree upon fair and reasonable prices with the selected A&E for a fixed price contract.

c. Percentage of Estimate Construction Cost

A&E fees have also been estimated as a percentage of the estimated construction cost. Graphs and/or schedules with suggested fees were prepared by the professional societies and distributed to their membership. Fee ranges were developed from experience and reflected an "average" fee which could be adjusted to meet the particular design effort at hand [Ref. 29]. Due to the Navy policy of using detailed analysis for estimating, "the use of a percentage of the estimated construction cost as a means of determining A&E compensation is prohibited" [Ref. 30]. However, the percentage of estimated construction cost method can be used as a guideline in determining cost, especially in light of the six percent statutory limitation discussed later.

3. Developing the Estimate

a. Components of the Estimate

The estimate for an A&E contract consists of three separate parts or components. Appendix B shows a typical form used by both the government and the A&E firm in developing estimates. The three components are (1) Design--Section A, (2) Engineering Services--Section B, and (3) Construction Contract Support Services (CCSS)--Section C.

(1) Design--Section A. The design effort is presented in Section A. This effort is defined as the services required for "the production and delivery of designs, plans, drawings, and specifications for a construction project" [Ref. 31]. The design effort is estimated by determining the direct labor man-hours required for each discipline (project engineering, architectural, structural, mechanical, electrical, civil, landscape, specification/report writer, cost estimator, and typist) separated by professional and sub-professional capabilities. These separate man-hour requirements are then extended by the appropriate labor rate and totaled to arrive at the "total direct labor" (line 12, Appendix B). The indirect costs of the A&E firm are represented in the overhead rate. The overhead rate is applied to the total direct labor to compute the amount of overhead. An overhead rate of approximately 100% is prevalent throughout the A&E industry. The

American Institute of Architects (AIA) [Ref. 32] supports this rate in ". . . that experience has demonstrated that overhead almost equals salaries . . . ." The amount for profit is then added to the total of overhead and direct labor to determine the "total fee for design services" (line 16 of Appendix B).

(2) Engineering Services--Section B. Engineering services are those items required to develop the design of the construction project but not explicitly displayed in the design presentation. As shown on Appendix B, these items include subsurface investigation, topographic survey, field investigation, reproduction, other special cost, and travel. Fees for these items are negotiated as a lump sum to include direct cost, overhead, and profit.

Subsurface investigations include soil borings, mechanical analysis, related laboratory analysis, recommendations and reports as required. The total amount for subsurface investigation is a lump sum figure which also includes any required travel and standard equipment cost. If not practical to negotiate a lump sum, a unit price may be utilized and negotiations conducted to establish unit prices, with estimated quantities and a "not to exceed fee."

Topographic surveys include survey parties, computer time, engineering and draftsman services in determination of contour intervals, grade and slope conditions and other site requirements as necessary. The lump sum

figure for topographic survey work also includes any required travel and standard equipment cost.

The fee for field investigations shall cover the effort necessary to determine existing conditions. Work items included are evaluation of the adequacy of existing utility systems, structural condition of existing facilities, verification of existing as-built drawings, etc. Field investigation is negotiated in terms of man-days with an appropriate rate to include overhead and profit.

The category of other special cost includes numerous different items of work. Appendix C is a listing of items which fall into this category. However, the most commonly used items are Project Engineering Documentation (PED), conceptual studies, energy conservation studies, and solar energy studies.

Reproduction costs are for the reproduction of drawings and specifications in quantities as specified by the scope of work.

Travel expenses should be added on a lump sum basis only if the amount of the travel to be performed is relatively certain and the cost thereof can be computed with a good degree of certainty. In addition, travel costs should be computed on the same basis of allowability as that which is allowed under government travel regulations. If the amount of travel to be performed is uncertain, the contract should provide that the contractor will be reimbursed

for authorized travel. In accordance with the standardized government travel regulations in granting such authorization, the OICC should assure that the number of personnel performing travel and the proposed duration of the trip is necessary for adequate performance of the contract work. Normally, profit and overhead will not be allowed on travel expenses; however, if a large amount of travel is required, which will involve significant administrative expense in arranging tickets and preparing vouchers for reimbursable travel, a reasonable overhead charge may be allowed on the amount of travel reimbursed. [Ref. 33]

(3) Construction Contract Support Services--Section C. Construction Contract Support Services (CCSS) are negotiated as an option to the government available for a period of time following the final design submittal. Usually, the time period is 360 days. CCSS items are negotiated in terms of hours required at an hourly rate with overhead and profit. There are two components of Section C: (1) shop drawing review and office consultation and (2) as-built drawing preparation.

Office consultation includes the necessary services of the A&E to clarify the intent and interpretation of the plans and specifications, to provide advice on questions that may arise in connection with the construction project and to provide office consultations in connection with contemplated changes as well as consultations during

negotiation of change orders to the construction contract. Shop drawing review includes services to assist with the inspection of all materials and equipment which will be incorporated in the finished construction project. Additionally, the A&E will be required to check all shop drawings, samples, catalog cuts, manufacturers' certificates, and also purchase orders which may be submitted by the construction contractor.

As-built drawing preparation includes entering all changes and corrections on the original tracings of the project drawings that developed during project construction. These changes are provided to the A&E on "marked-up prints" by the OICC showing the "as-built" condition and includes written modifications to drawings issued in either amendments or contract modification.

b. Statutory Limitations

Public law (10 U.S.C. 7212) requires that the design fee for public works or utilities projects may not exceed six percent of the estimated construction cost of the project. The six percent ceiling applies only to the procured A&E services for the production and delivery of designs, plans, and specifications for a construction project. As such, the "total fee for design services," line 16 on Appendix B, is the figure subject to this ceiling. The Armed Services have interpreted the statute such that the cost associated with Sections B and C do not apply to this

limitation. The validity of this interpretation has been upheld under numerous congressional reviews and rulings by the Comptroller General. [Ref. 34]

The six percent cost limitation is often too low for designing small dollar value projects and unique facilities. In making this observation, the Defense Audit Service [Ref. 35] recommended that the statute be revised to increase the ceiling for small dollar value and unique construction project. It was noted that often design work for these projects must be accomplished in-house by the engineering organization because A&E firms would not do the work within the six percent maximum. In a response to the Defense Audit Service's draft report, the Commander, Naval Facilities Engineering Command did not concur with this recommendation. This response was based on the opinion that increasing the statute would "result in unwarranted inflationary trends, relative to the value of the facilities designed" [Ref. 36].

III. METHODOLOGY

A. DEVELOPING THE DATABASE

1. General

The data for the research was collected at the Western Division, Naval Facilities Engineering Command, San Bruno, California (WESTNAVFACENGCOM). A&E contracting at WESTDIV is about one third of the NAVFACENGCOM total. The number of awards and total dollar amounts are as follows: [Ref. 37]

Fiscal Year	Awards	Modifications*	Dollar Total	Percentage of NAVFACENGCOM Total
76	171	58	$ 6,360,000	9.4%
77	225	631	23,009,000	31.7%
78	234	973	33,492,000	33.4%
79	187	1,024	30,288,000	33.1%
80	178	1,075	28,963,000	31.4%

The data was retrieved from the contract files held by the Contracts Division, Code 02. The Negotiation Board report was the source document with the attached government estimate and the A&E's fee proposal. Accordingly, the data collected was that of the negotiated contract reflecting the initial agreement reached between the A&E firm and the government negotiators.

*Modifications include changes, awards of options, award of final design, open-ended contract awards, etc.

The database consisted of 300 A&E contracts: 134--FY 79, 158--FY 80, 8--FY 81. This total was essentially all A&E contracts for these fiscal years that were available in the contracts files room from 10 April 81 to 17 July 81. This statement is qualified with several exceptions. Engineering Service (E/S) contracts were not included as this research was directed towards A&E contracts resulting in construction design. Each subsequent award on an open-ended contract was considered a separate contract as each award is for a different project which requires a separate negotiation process. Thirteen A&E contracts had various components of the fee itemization that were too large (too many digits) to fit the structure of the database. Four A&E contracts were working at the 35% design stage with the final design not yet negotiated. Changes negotiated for additional scope to an initial award were not included since the change order negotiations cannot be considered to be independent of the initial award. The 300 contracts represented 83% of all the contracts for FY 79 and 80, and all A&E contracts available for FY 81.

2. <u>Components</u>

Seventy-five pieces of information were recorded for each contract from the negotiation board report, the A&E fee proposal, and the government estimate. Some of the components are self-evident while others require an explanation or were coded to facilitate computer recording.

a. Year--The calendar year of the negotiation.

b. Month--The month of the negotiation.

c. Open-Ended--A coded-numerical entry indicating if the contract was awarded under the open-ended contract provision:

   0--Not an Open-Ended Contract
   1--An Open-Ended Contract

d. Estimated Construction Cost--This figure represented the dollar scope of the construction project.

e. Category Code--A coded-numerical entry to describe the facility being constructed, repaired, etc:

   1--Operation and Training Facilities
   2--Maintenance and Production Facilities
   3--Research, Development, Test and Evaluation Facilities
   4--Supply and Warehouse Facilities
   5--Hospitals, Medical and Dental Clinics
   6--Administration Facilities
   7--Community Facilities (Barracks, Dining, Recreational)
   8--Utilities
   9--Ground Structures
   0--Family Housing

f. Work Code--A coded-numerical entry to describe the type of work:

   1--New Construction
   2--Repair, Maintenance, Repair by Replacement
   3--Alterations, Modifications, Expansions
   4--Equipment Installations
   5--Retofit Projects (Safety, Pollution Abatement, Energy Conservation

g. Lead Discipline Code--A coded-numerical entry to describe the nature of the required work by which design discipline provided the most man-hours, professional and sub-professional:

   1--Project Engineer
   2--Architectural
   3--Structural
   4--Mechanical
   5--Electrical
   6--Civil
   7--Landscape

h. Number of Drawings--The total number of drawings required to present the construction project as agreed to during negotiations.

i. Hours--Nine different totals for direct labor hours were summarized as follows: professional engineers, sub-professional engineers, the specifications writer, the cost estimators, typist, professional and sub-professional shop drawings, and professional and sub-professional as-built drawing preparation.

j. Total Direct Labor--The total of direct labor hours times the various labor rates.

k. Overhead Rate--The negotiated overhead rate to cover the indirect cost of the A&E firm.

l. Profit Rate--The profit rate as negotiated which is commensurate with contract risk.

m. Total Design Cost--The dollar amount presenting the total of Section A computed by applying the overhead and profit rate to the amount of total direct labor.

n. Engineering Support, Section B--There were eleven different totals recorded from Section B of the contract. Detailed explanations of each is not necessary due to the self-evident title of each. The following were recorded for each contract: the cost of reproducing the plans and specifications, the cost of subsurface investigations, the cost of topographic surveys, the number of days of field investigation, the cost of field investigation, travel cost, project engineering documentation, conceptual studies, energy conservation studies, solar energy studies, and the total cost of all of Section B.

o. Construction Contract Support Services, Section C--The total for Section C was recorded which provides for future options to the contract for the government to procure these services.

p. Grand Total Fee--The bottom line negotiated total for the A&E contract.

q. Location Code--The geographical location of the project site was recorded with a numerical code as follows:

1--Adak, Alaska
2--Washington and Oregon

3--Northern and Central California (San Francisco Bay Area)
4--Los Angeles Area
5--San Diego Area
6--Yuma, Arizona

r. Number of Disciplines--The complexity of the A&E contract was measured as a function of the number of different design disciplines required to perform the design work. A numerical entry was used quantifying the total number of different design disciplines. The maximum number was seven with a minimum of one.

s. ENR Building Cost Index--Engineering-News Record (ENR) Magazine publishes various cost indexes of construction-related economic factors. The Building Cost Index (BCI) is one of these economic indicators. The BCI represents the cost for a constant amount of labor and building materials and is computed for different geographical locations. The BCI is computed for three geographical areas of WESTNAVFACENGCOM: Seattle, San Francisco, and Los Angeles. The BCI breakdown by geographical areas is provided on a monthly basis. Therefore, the published BCI that was recorded for each contract corresponded to the closest geographical area and to the closest date of contract negotiation. Additionally, ENR provides forecast of future cost trends by projecting the BCI for a twelve month period. These forecasts can be used in projecting cost on future A&E contracts.

t. Hours Per Drawing--Eighteen entries were recorded pertaining to the man-hours per drawing. For each of the six design disciplines, the following three items were recorded: (1) the number of drawings required for each discipline, (2) the professional design hours per drawing and (3) the sub-professional design hours per drawing.

u. Labor Rates--The final items that were recorded were the twenty different labor rates.

3. Compilation

The database was compiled using FORTRAN programming language with the WATFIV-S Compiler [Ref. 38] on the IBM 370 computer at the Naval Postgraduate School. Each contract required four 80-column key punched data cards. The data

was structured in a one-dimensional array, which was read, printed, and recalled for computations with conditional statements and counted do-loops. An example of the print-out for one contract is shown in Appendix D.

B. DESCRIPTION OF THE DATABASE

1. General

There were eight descriptive factors for each contract included in the database. These factors were used to group the contracts to determine trends, comparisons, and differences of the analytical computations performed to support the cost estimation decision process. Not all descriptive factors were considered to be relevant to all computations. The matrix in Appendix E shows the relevant relationships between descriptive factors and computations. An analysis of the database is provided by each of these descriptive factors.

2. Category Code

The type of facility being repaired, constructed, etc. was coded as defined in the previous section. A breakdown of the 300 contracts into the ten codes is as follows:

Code	Type of Facility	Number	Percentage
0	Family Housing	17	6
1	Operational & Training	56	19
2	Maintenance & Production	43	14
3	RDT&E	2	1
4	Supply	16	5
5	Medical	10	3
6	Administrative	8	3
7	Community	48	16

8	Utilities	82	27
9	Ground Structures	18	6

Due to the small number of Code 3 facilities, RDT&E projects were eliminated as a separate grouping for further analysis. The sample size was too small to achieve statistical significance.

Code 8, the Utilities group, included any project if the majority of the work involved utility systems. For example, an air conditioning repair project in an operational facility was coded as an "8", instead of a "1" for the Operational and Training facilities group.

3. Number of Disciplines

This code was a count of the number of different engineering disciplines involved in the project. The range was from one to seven with the following distribution:

Code	Number	Percentage
1	7	2
2	70	23
3	52	17
4	50	17
5	52	17
6	37	12
7	32	11

4. Estimated Construction Cost (ECC)

The database was separated into nine different ranges of estimated construction cost. These groups were used to relate contracts of similar dollar value to determine the effect of project scope.

Range of ECC	Number	Percentage
Up to - $ 50,000	38	13
$ 50,001 - 100,000	52	17
100,001 - 250,000	65	22
250,001 - 500,000	66	22
500,001 - 750,000	20	7
750,001 - 1,000,000	18	6
1,000,001 - 2,500,000	24	8
2,500,001 - 5,000,000	11	4
5,000,001 - And up	6	2

5. Lead Code

The engineer discipline which provided the most hours was coded corresponding to the number on Appendix B.

Lead Code	Number	Percentage
1--Project Engineer	3	1
2--Architect	119	40
3--Structural	20	7
4--Mechanical	81	27
5--Electrical	37	12
6--Civil	37	12
7--Landscape	3	1

6. Location

The geographical area of WESTNAVFACENGCOM was separated into six groups.

Code	Location	Number	Percentage
1	Adak, Alaska	13	4
2	Washington/Oregon	39	13
3	Northern California	74	25
4	Los Angeles Area	84	28
5	San Diego Area	84	28
6	Yuma, Arizona	6	2

Codes 1 and 6, although with relatively small sample sizes, were separated due to the remoteness of these areas. The three geographical ENR Building Cost Indexes for the WESTNAFVACENGCOM area combined these groups as follows:

(1) Seattle, Codes 1 and 2; (2) San Francisco, Code 3; (3) Los Angeles, Codes 4, 5 and 6.

7. Open-Ended Contracts

The breakdown of contracts awarded under the open-ended contract provision compared to contracts of similar scope which were not awarded as open-ended contracts is as follows:

	Number	Percentage
Open-Ended Contracts	107	36
Not Open-Ended	193	64
Not Open-Ended, but under $40,000	104	54

8. Work Code

The work code separated the database into groups of different types of work as follows:

Code	Type of Work	Number	Percentage
1	New Construction	89	30
2	Repair	95	32
3	Alteration, Expansion	75	25
4	Equipment Installation	10	3
5	Retrofit	31	10

9. Date

The negotiation date of the contracts in the database covered a thirty month time frame from January 1979 to June 1981. On a quarterly basis, the contracts were distributed as follows:

Quarter Midpoint	Number	Percentage
DEC 78	6	2
MAR 79	24	8
JUN 79	18	6
SEPT 79	30	10

DEC 79	33	11
MAR 80	48	16
JUN 80	39	13
SEPT 80	42	14
DEC 80	27	9
MAR 81	33	11

C. ANALYTICAL COMPUTATIONS

1. General

Analytical computations of the database were structured to support the decision processes presented on figures 1 and 2. The analysis was separated into four areas: the design section--Section A, engineering support--Section B, construction support services--Section C, and by labor rates. The analytical computations were first performed using the entire database as one group of data. Then, the same computations were done on each of the groupings of contracts described in the previous section of this chapter. The sample size, average, and standard deviation were calculated for each of the computations. An analysis of the results for each of these groupings was conducted to determine trends, similarities and differences.

2. Cost Adjustments

The level of effort for design work can be defined by quantities such as the labor hours and number of drawings. These levels of effort quantities would be constant for any particular project, in that these measures would not change over time for an identical project. Whereas, the impact of time on cost needs no explanation. Therefore, any

computation which involved cost and physical quantities was adjusted to a constant dollar base. The ENR Building Cost Index (BCI) was used as the economic adjustment factor. Appendix F displays the BCI for the three geographical areas of WESTNAVFACENGCOM. A BCI of 303 (March 1980) was used as the adjustment figure. This was the time period when the BCI for all three areas was equal. Additionally, this time period contained the largest proportion (16%) of the database.

3. Section A

The following analytical computations were performed for Section A:

a. The estimated construction cost was divided by the number of drawings to determine the amount of construction cost presented on a drawing.

b. The total design cost was divided by the number of drawings to determine the cost per drawing.

c. The number of drawings for each discipline was divided by the total number of drawings to determine on a percentage basis, the separation of drawings by discipline.

d. The hours per drawing were determined for the project engineer and the six design disciplines, both professional and sub-professional, and a total for all design hours. Additionally, the hours per drawing for the design support effort, the specifications writer, cost estimator, and typist were determined. Finally, sub-totals for the professional, sub-professional, and grand total of all labor hours per drawing were calculated.

e. The estimated construction cost was divided by two totals of labor hours to determine the relationship between estimated construction cost and labor hour requirements. The two totals were the design hours (professional and sub-professional) and the grand total for all labor hours.

f. Six percentages of labor hour ratios were computed as follows: (1) professional design and (2) sub-professional design to total design hours and (3) total professional, (4) total sub-professional, (5) design support, and (6) total design hours to the grand total of all labor hours.

g. Ratios of professional design hours to the three totals of design support (specifications writer, cost estimator, and typist) hours were computed to determine the required levels of design support. Additionally, the ratio of specification writer hours to typist hours was computed considering the close relation of these two disciplines.

h. The average rates for overhead and profit were computed as well as an average of the percentage of the Section A total to estimated construction cost with consideration for the 6% statutory limitations.

4. Section B

The following analytical computations were performed for Section B:

a. An average cost was computed for the sub-surface investigations and topographic surveys sections.

b. The estimated construction cost was divided by the number of man-days of field investigation to determine the relationship between the two. Additionally, the cost of field investigation was divided by the number of man-days to determine a unit cost per man-day.

c. The cost of reproducing the drawings and specifications was divided by the number of drawings to determine the cost per drawing.

d. The cost of travel was computed as a percentage of estimated construction cost.

e. The total for the "other special cost" was not used due to the numerous different items included in the sub-section. However, the four items most commonly found as a special cost were project engineering documentation, conceptual studies, energy conservation studies, and solar energy studies. An average amount was computed for each.

f. The total for Section B was computed as a percentage of the estimated construction cost.

5. Section C

The following analytical computations were performed for Section C:

a. The two totals of hours for shop drawing review, professional and sub-professional, were divided by the number of drawings to determine hours per drawing.

b. The two totals of hours for as-built drawing preparation, professional and sub-professional, were divided by the number of drawings to determine hours per drawing.

c. The total for Section C was computed as a percentage of the estimated construction cost.

6. Labor Rates

An average for each labor rate was computed using the entire database. Then, an average for each of the three years (1979, 1980, 1981) was computed to determine the percentage of wage increase over those years. Additionally, an average for each labor rate was computed for each of the six geographical locations.

7. Analysis of Descriptive Factor Groupings

a. General

The analytical computations described in the previous section were performed on the complete database. Accordingly, the results from these computations defined inferences particular to the complete database. While this information may be quite beneficial to the EIC in developing an estimate, information generated from computations which

separate the contracts by descriptive factors, to be similar to the project being estimated, would intuitively be more relevant.

Therefore, the next step of the analysis was to perform all the analytical computations for each group of descriptive factors separated by the various components of each group, such as by codes and ranges of estimated construction cost. As with the complete database, the sample size, average, and standard deviation was calculated for each computation.

With these three pieces of information for each computation, the task was to determine if the various codes within a group generated a statistical significant difference within that grouping of contracts. For example, the question to be answered, "Is the average amount of estimated construction cost per drawing significantly different between the ten category codes of facilities?", or in other words, "Does the type of facility have an impact on the estimated construction cost per drawing?"

As mentioned earlier, not all combinations of descriptive factors and analytical computation were considered to be relevant. The combinations that were tested are shown in Appendix E.

Four methods were used to determine and present the differences generated by descriptive factors. These

methods included computing confidence intervals, performing multiple contrast, tables of averages, and differences of means.

b. Confidence Intervals

A confidence interval is an estimate that covers a range of values distributed on both sides, plus or minus, of a mean or average. With a predetermined level of confidence, the interval can be constructed based on an average plus or minus the sampling error [Ref. 39]. For the purposes of this analysis, a confidence level of 95% was used. Accordingly, with the sample size, average, and sample standard deviation a confidence interval can be constructed, such that 95% of the population values for a given computation will fall within the range of values covered by that interval.

Confidence intervals were used to present the ranges of plausible values for the analytical computations that can be considered to be most subjective on the part of the estimator. The information presented in this form will allow comparison of ranges of values for different descriptive factors.

Confidence intervals were used for the following computations: Section A--the estimated construction cost per drawing, cost per drawing, and the Section A% of estimated construction cost; Section B--The sub-surface investigation, topographic survey, estimated construction cost per day of field investigation, and the Section B% of estimated

construction cost; Section C--the Section C% of estimated construction cost.

c. Multiple Contrast

The technique of multiple contrast is a follow-on of the analysis of variance. When the analysis of variance indicates that one or more means in a group has been determined to be significantly different from the group, the multiple contrast will determine which mean(s) are significantly different. For this analysis, the analysis of variance will be omitted, assuming a difference does exist, and go straight to the multiple constant technique.

The multiple contrast provides simultaneous contrast of all means with a group by constructing simultaneous confidence intervals based on the F distribution. Additionally, these confidence intervals are based on the pooled variance of all entries in the group. [Ref. 40]

The multiple contrast was used for those computations which may be effected by the descriptive factor but are not as subjective as those presented by the confidence intervals listed in the previous section. The multiple contrast was used for the following computations: Section A--the estimated construction cost divided by the two totals of labor hours, the ratios of professional design hours to design support hours, and the overhead rate; Section B--the cost of the field investigation per man-day, the cost of reproduction per drawing, travel, and the four items of

other special cost; Section C--the professional and sub-professional hours per drawing for shop drawing review and as-built drawing preparation.

d. Tables of Averages

The table format was used to present the averages of computations which are fairly objective on the part of the estimator. This format will be used for the hours per drawing and the labor rates.

8. Open-Ended Contracts

The contracts awarded under the open-ended contract provision will be compared to those not awarded as open-ended but have a fee under $40,000 which is a requirement for an open-ended contract. The comparison will be accomplished by the difference in two means technique. The technique involves constructing a confidence interval based on the variances of the two values and added to or subtracted from the difference in the two means. "No difference" of the two means is concluded when zero is contained within the confidence interval [Ref. 41]. A 95% confidence interval will be computed for the difference in means for the Section totals for A, B, and C as a percentage of estimated construction cost.

D. COST MODEL FORMULATION

Cost models applied to A&E contract estimation may be beneficial to the EIC in determining "ballpark" totals to be

used as a guide in developing detailed estimates. Additionally, cost models may be applied to the budgeting and planning function for developing an annual A&E contracting program. Accordingly, the model should be easy to use and should be reliable.

At the point where design of a project is being considered, the estimated construction cost of the project has been established. Therefore, it would be an appropriate variable. Another variable, which can be defined at this point, would be the number of different design disciplines required for the design work. These two variables would provide more definition to the particular project than estimated construction cost alone.

Since a cost model would be used in a planning or guideline capacity, the values that the model is predicting should be totals and/or significant sub-totals associated with the contract. Accordingly, the six dependent variables were as follows: the grand total fee of the A&E contract, the totals for Sections A, B, and C, the total of professional design hours, and the number of drawings.

The multiple linear regression program (BMDP1R) of the Department of Biomathematics, University of California, Los Angeles, installed on the computer facilities at the Naval Postgraduate School, was used to develop a cost model for A&E contract estimation.

IV. COST ESTIMATION MODELS

A. SECTION A

1. Number and Cost of Drawings

The estimated construction cost divided by the number of drawings produced an average of $27,551 with a standard deviation of $23,019, which provided a confidence interval of $24,946 to $30,155. Therefore, the required number of drawings can be predicted by estimating one drawing for each $24,946 to $30,155 of estimated construction cost.

The category code, range of estimated construction cost, and work code were the three descriptive factors which affected this average. The limits of the confidence intervals for these factors are shown in Appendix G.

The total design cost divided by the number of drawings produced an average of $1,370 with a standard deviation of $945 which provided a confidence interval of $1,263 to $1,476. Therefore, the total design cost (Section A) can be predicted by estimating $1,263 to $1,476 for each drawing.

The category code, range of estimated construction cost, and work code were the three descriptive factors which affected this average. The limits of the confidence interval for these factors are shown in Appendix G.

2. Drawings by Design Discipline

The number of drawings for each discipline divided by the total number of drawings produced the following distribution by discipline on a percentage basis:

Design Discipline		Percentage of Total Drawings
Architectural	-	27%
Structural	-	12%
Mechanical	-	25%
Electrical	-	21%
Civil	-	13%
Landscape	-	2%

The lead discipline was the descriptive factor which affected the percentage of drawings by discipline. A table of averages showing the distribution of drawings by lead code is shown in Appendix G.

3. Hours Per Drawing

Five tables of averages for hours per drawing are provided in Appendix G. Each table also shows a confidence interval for hours per drawing when all contracts were considered as one group. The five tables are for category code, range of estimated construction, lead discipline code, work code, and by number of disciplines.

4. Estimated Construction Cost Per Labor Hour

The estimated construction cost divided by the total design hours produced an average of $652/hour with a standard deviation of $238, which provided a confidence interval of $625 - $680 per hour. Therefore, the required number of total design hours (professional and sub-professional) can

be predicted by estimating one design hour for each $625 to $680 of estimated construction cost.

Additionally, the estimated construction cost divided by the total labor hours produced an average of $486/hour with a standard deviation of $174, which provided a confidence interval of $466 to $505 per hour. Therefore, the required number of total labor hours can be predicted by estimating one labor hour for each $466 to $505 of estimated construction cost.

Category codes, ranges of estimated construction cost, and work codes were the descriptive factors which affected the estimated construction cost per labor hour computations. Confidence intervals for these factors are provided in Appendix G.

5. Labor Ratios

a. Design Hours--Professional/Sub-Professional

The average percentage of separation for design hours into professional and subprofessional is 44% and 56% respectively, with an equal standard deviation of 14%. Confidence intervals for these computations were:

Professional Design	42% to 46%
Sub-Professional Design	54% to 58%

The multiple contrast technique indicated no difference in these averages due to category code or ranges of estimated construction cost. However, the multiple contrast by lead code indicated different averages (53%--professional, 47%--

sub-professional) when the structural discipline was the lead code. The confidence interval for lead code 3 is as follows:

Professional Design	46% to 59%
Sub-Professional Design	41% to 54%

b. Total Hours--Professional/Sub-Professional

The average percentage of separation for total labor hours into professional and sub-professional is 49% and 51% respectively, with an equal standard deviation of 12%. Confidence intervals for these computations were:

Professional	48% to 50%
Sub-Professional	50% to 52%

Again, the different significant descriptive factor was the lead code for structural projects (57%--professional, 43%--sub-professional). The confidence interval for lead code 3 is as follows:

Professional	52% to 62%
Sub-Professional	38% to 48%

c. Design/Design Support

The average percentage of separation for total hours into design and design support is 81% and 19% respectively, with an equal standard deviation of 12%. Confidence intervals for these computations were:

Design	80% to 82%
Design Support	18% to 20%

The upper and lower ranges of estimated construction cost were the factors affecting this computation. When the estimated construction cost was under $50,000, the average

separation was 72% and 28%. When the estimated construction cost was over $5,000,000, the average separation was 87% and 13%. Confidence intervals for these exceptions are as follows:

ECC under $50,000

Design	67% to 76%
Design Support	24% to 33%

ECC over $5,000,000

Design	82% to 92%
Design Support	8% to 13%

6. Design Support Hours

a. Specification Writer

The hours for professional design divided by the hours for the specifications writer produced an average of 5 with a standard deviation of 4, which provided a confidence interval of 4 to 6 hours. Therefore, the hours for the specifications writer can be predicted by estimating one hour for every 4 to 6 hours of professional design.

The estimated construction cost of projects over $1,000,000 affected this computation. An average of 8 hours with a standard deviation of 5 resulted in a confidence interval of 6 to 10 hours.

b. Cost Estimator

The hours for professional design divided by the hours for the cost estimator produced an average of 6 with a standard deviation of 4, which provided a confidence interval of 5 to 7 hours. Therefore, the hours for the cost

estimator can be predicted by estimating one hour for every 5 to 7 hours of professional design.

As with the specifications writer, the descriptive factor affecting this computation was the estimated construction cost. When estimated construction cost was under $50,000, the average was 4 and when over $1,000,000, the average was 10. Confidence intervals for these factors are as follows:

ECC under $50,000

Professional design per cost estimator: 3 to 5

ECC over $1,000,000

Professional design per cost estimator: 8 to 12

c. Typist

The hours for professional design divided by the hours for the typist produced an average of 6 with a standard deviation of 6, which provided a confidence interval of 5 to 7 hours. Therefore, the hours for the typist can be predicted by estimating one hour for every 5 to 7 hours of professional design.

The estimated construction cost had an impact on this computation. For projects under $250,000, the average was 4 and projects over $5,000,000 the average was 19. Confidence intervals for these exceptions are as follows:

Professional design per typist

ECC under $250,000: 3 to 5
ECC over $5,000,000: 7 to 30

d. Specifications Writer/Typist

The hours for the specifications writer divided by the typist produced an average of 1 with a standard deviation of 1. This relationship is best described as a 1 to 1 ratio between these two disciplines. However, for construction projects larger than $750,000, the ratio was 2 specification writer hours to 1 typist hour.

7. <u>Overhead</u>

The average overhead rate was 104% with a standard deviation of 14% which provided a confidence interval of 102% to 106%. The average overhead was affected by three descriptive factors: number of disciplines, location, and lead discipline code.

When only one discipline was required for the contract, the overhead was lower with an average of 95%. The confidence interval for this average was from 90% to 100%.

One location significantly affected the overhead which was Adak, Alaska with an average overhead of 118%, with a confidence interval from 105% to 130%.

The lead discipline code resulted in three significantly different overhead rates, one lower and two higher.

When the lead code was mechanical, the average overhead was 100%. This provided a confidence interval from 98% to 102%.

Structural and civil engineering projects had higher overhead rates, 116% and 117% respectively. Confidence intervals for these rates are as follows:

Structural:	105% to 126%
Civil:	110% to 124%

8. <u>Profit</u>

The profit rate was 10% throughout all descriptive factors, except for projects where the lead discipline was the project engineer or structural engineer. These projects had an average of 11% for profit.

9. <u>Section A Percent of ECC</u>

The total for Section A divided by the estimated construction cost produced an average of 5.39% with a standard deviation of .85%. This provided a confidence interval of 5.29% to 5.48%. The limits of confidence intervals when separated by category codes, estimated construction cost, and work codes are shown in Appendix G.

B. SECTION B

1. <u>Sub-Surface Investigations</u>

The average amount negotiated for sub-surface investigation was $3,862 with a standard deviation of $2,919, which provided a confidence interval from $3,195 to $4,528. As a percentage of estimated construction cost, the interval

was from 0.54% to 0.86%. Confidence intervals and average percentages of estimated construction cost negotiated for sub-surface investigation broken down by range of estimated construction cost and work code are shown in Appendix H.

2. Topographic Survey

The average amount negotiated for topographic survey was $3,994 with a standard deviation of $3,945, which provided a confidence interval of $3,945 to $4,735. As a percentage of estimated construction cost, the interval was from 0.96% to 1.83%. Confidence intervals and average percentages of estimated construction cost are shown in Appendix H.

3. Field Investigations

The estimated construction cost divided by the number of man-days of field investigation produced an average of $59,407/man-day with a standard deviation of $154,843, which provided a confidence interval of $41,766 to $77,047 per man-day. Therefore, the required number of man-days of field investigation can be predicted by estimating one man-day of field investigation for every $41,766 to $77,047 of estimated construction cost.

Category codes, ranges of estimated construction cost, and work codes were the descriptive factors which affected this computation. Confidence intervals for these factors are shown in Appendix H.

The average cost per man-day of field investigation was $271 with a standard deviation of $107, which provided a confidence interval of $258 to $283 per man-day. The multiple contrast was computed for the work codes, location, and lead codes. There was no difference amongst the averages for the five work codes. However, location did affect average cost. The average for Adak was higher at $470 per man-day and Yuma was lower at $230. Additionally, projects with a lead code of "1", project engineer, was a higher average at $357 per man-day. Confidence intervals for these exceptions are as follows:

Location Code

Adak:	$222 to $718
Yuma:	$202 to $258

Lead Code

Project Engineer:	$280 to $434

4. Reproduction Cost

The cost of reproduction for the plans and specifications divided by the number of drawings produced an average of $69 per drawing with a standard deviation of $47, which provided a confidence interval of $63 to $74 per drawing. Therefore, the cost for reproduction can be predicted by estimating $63 to $74 per drawing. The multiple contrast comparison for location indicated two exceptions. The average cost for Adak per drawing was $88 and $82 for

Location Code 2, Washington and Oregon area. Confidence intervals for these two locations are as follows:

Adak:	\$61 to \$115
Washington/Oregon:	\$60 to \$107

5. Travel

The cost of travel computed as a percentage of estimated construction cost produced an average of 0.4% with a standard deviation of 0.6% which provided a confidence interval of 0.31% to 0.48%. The multiple contrast for location indicated one exception: Adak. The average for travel to this location was 1.0% of the estimated construction cost with a confidence interval of .5% to 1.5%.

6. Other Special Costs

a. Project Engineering Documentation (PED)

The average amount for PED was \$3,212 with a standard deviation of \$1,805, which produced a confidence interval of \$2,688 to \$3,735. PED cost computed as a percentage of estimated construction cost produced an average of 0.6% with a standard deviation of 0.6%, for a confidence interval of 0.42% to 0.77%. Multiple contrast for location and range of estimated construction cost did not indicate any exceptions.

b. Conceptual Studies

The average amount for conceptual studies was \$9,664 with a standard deviation of \$9,236, which provided a confidence interval of \$5,851 to \$13,476. The cost of

conceptual studies computed as a percentage of estimated construction cost produced an average of 0.8% with a standard deviation of 0.6% for a confidence interval of 0.55% to 1.04%. Multiple contrast for location and range of estimated cost did not indicate any exceptions.

c. Energy Conservation Studies

The average amount for energy conservation studies was $3,949 with a standard deviation of $2,257, which provided a confidence interval of $2,892 to $5,005. The cost of these studies computed as a percentage of estimated construction cost produced an average of 0.3% with a standard deviation of 0.2% for a confidence interval of 0.2% to 0.4%. Multiple contrast for location and range of estimated construction cost did not indicate any exceptions.

d. Solar Energy Studies

The average amount for solar energy studies was $2,464 with a standard deviation of $1,585 which provided a confidence interval of $1,675 to $3,253. The cost of these studies computed as a percentage of estimated construction cost produced an average of 0.2% with a standard deviation of 0.2% for a confidence interval of 0.1% to 0.3%. Multiple contrast for location and range of estimated construction cost did not indicate any exceptions.

7. Section B Percent of ECC

The total for Section B divided by the estimated construction cost produced an average of 3.92% with a

standard deviation of 3.98%. This provided a confidence interval of 3.46% to 4.37%. The limits of confidence intervals when separated by category codes, estimated construction cost, and work codes are shown in Appendix H.

C. SECTION C

1. Shop Drawings and Office Consultation

The hours for shop drawing review and office consultation divided by the number of drawings produced averages of 2.7 hours per drawing and 1.6 hours per drawing, professional and sub-professional respectively, with standard deviations of 2.0 and 1.0. Confidence intervals are as follows:

Professional:	2.4 to 2.9 Hours/Drawing
Sub-Professional:	1.4 to 1.8 Hours/Drawing

Multiple contrast comparisons were computed for category codes, lead codes, and work codes. The following averages were exceptions:

	Average	Confidence Interval
Professional		
Work Code 5--Retrofit	1.5	1.0 to 2.0
Sub-Professional		
Lead Code 5--Electrical	1.2	0.97 to 1.4
Lead Code 6--Civil	1.2	0.8 to 1.6

2. As-Builts Drawing Preparation

The hours for as-built drawing preparation divided by the number of drawings produced averages of 1.0 hours per

drawing and 1.9 hours per drawing, professional and sub-professional respectively, with standard deviations of 0.8 and 1.3. Confidence intervals are as follows:

Professional:	.9 to 1.1 Hours/Drawing
Sub-Professional:	1.7 to 2.1 Hours/Drawing

Multiple contrast comparisons were compared for category codes, lead codes, and work codes. The following averages were exceptions:

	Average	Confidence Interval
Professional		
Lead Code 3--Structural	1.7	0.9 to 2.6
Lead Code 5--Electrical	.7	0.6 to 0.9
Sub-Professional		
Lead Code 3--Structural	2.9	1.8 to 4.0

3. Section C Percent of ECC

The total for Section C divided by the estimated construction cost produced an average of 0.9% with a standard deviation of 0.6%. This provided a confidence interval of 0.8% to 1.0%. The limits of confidence intervals when separated by category code, lead code, and work codes are shown in Appendix I. Additionally the average for each range of estimated construction cost is provided.

D. LABOR RATES

1. Labor Rate Increase

The average labor rate for each discipline by year is shown in Appendix J, as well as the yearly increase in

those rates. Using a composite labor rate of all professional disciplines, an average increase of 8.8% was realized from 1979 to 1980. For the first six months of 1981, there was an increase of 5.2%. Likewise, there was an average increase of 3.6% in labor rates for the sub-professional disciplines from 1979 to 1980, and for the first six months of 1981, the increase was 5.1%.

2. Labor Rates by Location

A separation of labor rates by location is provided in Appendix J. A comparison of the average rate by location to the average for all contracts indicates that the rates for projects in Adak, Alaska are substantially higher, while the rates for the Yuma, Arizona projects are lower. The rates for the other locations are much closer to the average for all contracts.

E. OPEN-ENDED CONTRACTS

1. Number of Awards

There were 107 open-ended contracts included in the database or 36% of the total. Likewise, there were 104 contracts which were not open-ended, but with a grand total fee under $40,000. Contracts under $40,000 can be awarded under the open-ended contract provision, provided the other qualifying requirements are met. Accordingly, if desired or directed by policy, there were enough contracts under the $40,000 limit to shift the open-ended awards from 36% to 70%

of all A&E contracts. Increasing the awards of open-ended contracts would be advantageous given the shorter lead time to award additional projects as change orders.

2. Cost Comparisons

Using the statistical technique, "difference of two means," the totals for Sections A, B, and C computed as a percentage of estimated construction cost for open-ended contracts were compared to those not awarded as open-ended, but under $40,000.

The confidence interval for the difference between Section A totals ranged from -0.036% to 0.376%. Since the "zero" value was included in the interval, there is statistically no difference between the average of 5.62% for open-ended contracts and the average of 5.45% for similar contracts, not open-ended, for the Section A total.

The confidence interval for the difference between Section B totals ranged from 0.62% to 2.3%. Accordingly, the open-end contract average of 4.79% for Section B is statistically higher than the average of 3.3% for similar contracts, not open-ended.

The confidence interval for the difference between Section C totals ranged from .013% to .386%. As with Section B, the open-ended contract average of 1.1% for Section C is statistically higher than the average of 0.9% for similar contracts, not open-ended.

Although the totals for Sections B and C are statistically higher for open-ended contracts, the difference is not significant in that the total percentage for B and C combined is approximately the same as Section A alone. Additionally, the cost of selection process is avoided by negotiating change orders with the same firm for additional projects as opposed to negotiating with a different A&E firm for each project. Therefore, given the cost for the two groups of contracts are similar and the advantages such as reduced lead time for awards, retention of high quality A&E firms for additional work, and reduced administrative cost, an increase in the use of the open-ended A&E contract provision is a viable alternative.

F. REGRESSION COST MODELS

1. Multicollinearity

Six cost models were developed using the estimated construction cost and number of design disciplines as the independent variables. The condition of multicollinearity between the two independent variables was not considered significant in that the correlation factor for these two variables was 0.4333. As such, the effect of a change in either variable on the dependent variable can be considered separately. This is intuitively predictable in that construction projects may have a relatively high cost while only requiring two or three design disciplines or a relatively

smaller project may require four or five design disciplines. In other words, the two variables are not necessarily related to each other.

2. Reliability of the Regression Equation

Three measures of reliability or exactness of fit are provided for each of the models. The coefficient of multiple determination, r^2, is an indication of the exactness of fit of the regression equation. A value of "1" is a perfect fit and "0" would indicate there is no relation between the independent and dependent variables.

The standard error of estimate, SEE, is the standard deviation of the dependent variable. The measure is based on the difference between the observed value of the dependent variable to the predicted value provided by the regression equation.

The F ratio is a measure of the variance explained by the regression divided by the unexplained variance. The F ratio is used in hypothesis testing. The hypothesis test would be to reject the null hypothesis that the variance is not explained by the regression. The prob-value, p, of the null hypothesis is the criteria for rejecting or not rejecting the hypothesis. Again using the 95% confidence level, a prob-value larger than 0.05 would indicate that the null hypothesis cannot be rejected meaning the regression is not explaining the variance. Therefore, with the computed F statistic and the corresponding prob-value, the hypothesis

testing can determine if the regressors (independent variables) are affecting the dependent variable. [Ref. 42]

As shown in the next section, the regressions produced models which can be considered reliable for cost estimation. The coefficient of multiple determination, r^2, was .7 or better for all models except for the Section B equation with a value of 0.49. This exception can be explained due to the numerous and different items of work that can be included in Section B. The F ratios were all very high which produced prob-values of 0.000. This indicates that the null hypothesis can be rejected for all equations, meaning that a significant portion of the variance for the dependent variable is explained by the regressions.

3. Regression Equations

a. Grand Total Fee

The grand total fee for the A&E contract can be predicted by:

$$\text{Grand Total Fee} = -3965.6 + .0532\ (\text{ECC}) + 3985.3\ (\text{No. of Disciplines})$$

$r^2 = .9253$ SEE = \$17,485

F ratio = 1840.6 $p = 0.000$

b. Section A Total

The total for design services can be predicted by:

$$\text{Section A} = -3804.3 + .0421\ (\text{ECC}) + 1788.4\ (\text{No. of Disciplines})$$

$r^2 = .9520$ SEE = \$10,680
F ratio = 2943.5 $p = 0.000$

c. Section B Total

The total for engineering services can be predicted by:

Section B = -60.7 + .0092 (ECC) + 1842.3 (No. of Disciplines)

$r^2 = .4913$ SEE = \$11,992
F ratio = 143.4 $p = 0.000$

d. Section C Total

The toal for construction contract support services can be predicted by:

Section C = -719.0 + .0043 (ECC) + 428.8 (No. of Disciplines)

$r^2 = .7718$ SEE = \$2,229
F ratio = 417.7 $p = 0.000$

e. Professional Design Hours (PDH)

The total labor hours for professional design can be predicted by:

PDH = -17.7 + .0006 (ECC) + 10.7 (No. of Disciplines)

$r^2 = .8806$ SEE = 245 hours
F ratio = 1094.7 $p = 0.000$

f. Number of Drawings (ND)

The total number of drawings can be predicted by:

ND = 1.14 + .000014 (ECC) + 2.13 (No. of Disciplines)

$r^2 = .7028$ SEE = 11 drawings
F ratio = 351.2 $p = 0.000$

V. APPLICATION OF THE DECISION PROCESS

A. GENERAL

1. Developing Estimates

The decision process and decision support approach to the cost estimation of A&E contracts should be applied as a supplement to and not as a substitute for the EIC's judgment and experience. This is a fundamental concept of decision support, in that the system should provide the means and not the ends for decision making. The information provided by this system is significant in that it is based on the judgment and experience of previous decisions very similar to the decisions currently necessary to develop an estimate. However, there has never been a construction project that was identical to another in all respects. The uniqueness of construction projects and consequently the design requirements reinforce the requirement for judgment as a major factor in the design estimation process. As such, the method an EIC may choose to apply the findings of the A&E contract database will no doubt be individualized, as they well should be.

The estimation worksheets included in Appendix K present one method of application. These forms are designed to serve as a transition from the findings presented in Chapter 4 to the A&E Fee Itemization form, Appendix B. The

worksheets provide equations to compute the values for key components of the estimate based on information derived from the database.

2. Cost Adjustments

The findings presented in Chapter 4 should be insensitive to time due to the cost adjustment factor built into the database, the Engineering News Record, Building Cost Index. As such, Section II of Appendix K provides the means to compute the cost adjustment needed by dividing the current BCI by the BCI of 303, on which the database was constructed. This adjustment factor multiplied by the various cost per unit quantities will keep pricing information up-to-date. Additionally, the findings of this thesis research could very well be applied at activities outside of the WESTNAVFACENGCOM area by using the current BCI for the given geographical location.

3. Confidence Interval Interpretation

The results of many analytical computations were presented as confidence intervals. This technique was chosen for those computations which involved much subjectivity. Additionally, when the confidence interval technique was used, the computation results were provided for three different descriptive factors. As such, applying this information to a different estimate is an example of the requirement for judgment on the part of the EIC in the decision process.

The method of application used in the work sheets is a high-low technique involving three steps: (1) fill in the code for the descriptive factor and the upper and lower limit for each confidence interval, (2) then annotate the smallest of the lower limits and the largest of the upper limits, and (3) compute an average of these two. This technique is rather simple and does consider the complete range of values for all descriptive factors which defined the current project. However, the judgment of the EIC may conclude that not all descriptive factors are pertinent and that only one or two best reflect the project currently being estimated.

4. Scoping Estimates

The purpose of a scoping estimate is to give the EIC an idea of approximate cost, a "ballpark" figure, or a point of departure in computing a detailed estimate. From the findings in Chapter 4 and by the techniques presented in the estimation worksheets, scoping estimates can be prepared in two methods: (1) using the regression models and (2) by the percentage of estimated construction cost influenced by descriptive factors. The results of the two methods will invariably be different, which will give an upper and lower range of possible values. These two methods are applicable for the totals of Sections A, B, and C. Additionally, a scoping estimate for Section A may be computed by the cartooning method, determine the number of drawings extended by

the cost per drawing. The regression model is the method for computing scoping estimates for the grand total fee (Section I, Appendix K). This model may also be applied in the planning stages for an A&E design budget.

5. <u>Detailed Analysis Method</u>

Given the requirement to develop A&E estimates by detailed analysis, the emphasis of the decision support application is directed towards computing the components of each section. As such, each section will be addressed separately.

B. DETAILED ANALYSIS PROCEDURES

1. <u>Section A</u>

The detailed analysis method identifies all requirements for design services in terms of labor hours. However, the quantity that needs to be computed first is the number of drawings. Two methods are provided to accomplish this computation: the regression model and by estimated construction cost per drawing. These methods are presented in Section III A of Appendix K. Then, the labor hours can be computed by the first two steps presented in Section III C of Appendix K: (1) the total number of drawings are separated by discipline and (2) the hours per drawing for each discipline are extended by the number of drawings to derive total hours.

Labor hours can also be computed based on the estimated construction cost method and by regression models as shown in Section III.C.3, 4, and 5. These totals will serve as "check" figures to the totals computed based on the number of drawings. Any additional labor identified will be those design hours which are not explicitly presented on a drawing.

The three labor ratios computed in Section III.C.6 of Appendix K will also serve as a "check" figure to ensure a proper distribution of different labor hour totals.

The labor hours for the three disciplines which constitute design support can be computed as a function of professional design hours. Again, these methods, Section III.C.7, of Appendix K, provide an alternative means of labor hour computations to the number of drawings method.

Once the required hours for each discipline is determined, the cost for Section A can be computed by applying labor (Appendix J), overhead and profit rates (Section III.C, 8 and 9 of Appendix K).

2. <u>Section B</u>

Estimating the cost for engineering support is fairly straightforward in that Section B is comprised of six different sub-totals, as shown on figure 2. The EIC must determine which of the six components are required for the project and estimate the cost separately for each to include all labor, equipment, overhead, profit, etc.

The amounts for sub-surface investigation and topographic survey are estimated by a similar procedure. The range of estimated construction cost and work code were the factors affecting these two estimates. Accordingly, confidence intervals for these two (Section IV.B.1 and 2 of Appendix K) provide upper and lower limits on total amounts. As with Section A computations, the EIC must determine the amount based on these two ranges of values.

The cost for field investigations involves two steps. First, the number of man-days must be determined, then the cost per man-day to derive a total. Computing the man-days was based on the estimated construction cost and the confidence intervals in Section IV.B.3 of Appendix K represent the amount of construction cost per man-day. By averaging the three intervals, a man-day estimate can be computed. The cost per man-day was based on the complete database with exceptions noted by location.

The cost for reproduction (Section IV.B.4 of Appendix K) can be estimated by extending the number of drawings by the cost per drawing. At this point, the number of drawings has been determined. The cost per drawing was determined by confidence intervals on the complete database with exceptions noted by location.

Estimates for other special costs are limited to project engineering documentation, conceptual studies, energy conservation studies, and solar energy studies

(Section IV.B.5 of Appendix K). Estimates for each of these can be computed as a percentage of estimated construction cost, then compared to the confidence interval computed by total amount to provide a "check" figure.

Travel was computed as a percentage of estimated construction cost and presented as a confidence interval (Section IV.B.6 of Appendix K). The confidence interval was based on the completed database with one exception by location.

3. Section C

The detailed analysis method for Section C, Construction Contract Support Services, involves determining the labor hours for each of the four sub-totals of the section: Shop Drawings--professional and sub-professional, and As-Built Preparation--professional and sub-professional (Section V.B.1, 2, 3 and 4). The labor hours for each sub-total is computed as a function of the number of drawings. The hours per drawing for each sub-total is presented as a confidence interval based on the complete database with exceptions as noted. With the four sub-totals of labor determined, the total for Section C is computed by applying the labor, overhead, and profit rates.

C. DECISION SUPPORT TEST CASES

1. General

Test cases of the decision process and decision support approach were accomplished by applying the system to A&E contracts not included in the database. The step-by-step procedures outlined in Appendix K were followed for three test cases. The results of each test case are presented in Appendix L. The results are presented in summary form showing key components for the government estimate, the negotiated price, and the estimate generated by the procedures of Appendix K. Additionally, the results for the scoping estimate techniques are shown as well as estimates computed by the detailed analysis method.

2. Test Cases

a. Test Case No. 1

This contract was for the rehab of the consolidated open mess in Adak, Alaska. The estimated construction cost was $200,000 and the A&E contract was negotiated in June 1981.

The scoping estimate techniques were accurate for this test case as computed values closely represented the negotiated price. However, the regression model for professional design hours predicted a much larger quantity of labor hours.

The detailed analysis method was very accurate in that the predicted value for the grand total fee was

within 7% of the negotiated price. An analysis of each section indicates that Section B was lower than the negotiated price due mainly to a difference in field investigation. Section C was lower in total price, but the labor hours estimates were higher. Likewise, the labor estimates in Section A were larger than both the government estimate and the negotiated price. However, when the labor hours were extended by labor rates with overhead and profit applied, the computed total exceeded the 6% limitation. Therefore, the estimate for Section A was capped at $12,000. Given this situation, it can be concluded that this test case demonstrates the effect of the 6% limitation, reducing the labor hours needed for design services. This conclusion is also supported by the general characteristics of this project: relatively small in scope, in a remote area, and a rehab project, which may have construction requirements unidentifiable in the design stage.

b. Test Case No. 2

This contract was for a road repair project in the San Diego area. The estimated construction cost was $637,000 and the A&E contract was negotiated in July 1981.

The scoping estimates for this contract were not as accurate as in test case number one. The grand total fee estimate was significantly lower than the government estimate and the negotiated total. However, the three Section A estimates were all accurate while being within 14% of the

negotiated total. The two techniques for Section B were quite divergent. Likewise, the two Section C estimates were widely spread and both higher than the negotiated figure. In this test case, all regression model estimates were the lowest and the highest were computed by the percentage of estimated construction cost method.

The detailed analysis method provided an excellent estimation of the grand total fee and was within 8% of the negotiated total. The labor hours estimates of Section A were representative of the negotiated values with slightly more professional hours and less sub-professional hours. Additionally, there were more hours estimated for design support and less for design. Comparing the estimates for Section B indicated mixed results. Field investigation and reproduction cost were higher with travel extremely too high. Additionally, topographic survey costs were estimated too low. The hours for Section C were all higher than the negotiated figure with total cost significantly higher. The grand total fee for this case was estimated quite accurately as was the Section A, design services. However, the bottom-line accuracy of this contract was the result of higher and lower estimates of each section offsetting each other. While the higher amount of Section C did not significantly affect the total, Section B needs emphasis on this test case. The range of values for these components varied greatly as did the scoping estimates. This again emphasizes the

importance of judgment on the part of the EIC to inject proper interpretation of the numbers. For example, this contract was for road repairs and as such, topographic survey would intuitively be a major component of the A&E contract. However, the decision support information did not provide a sufficient total for this component when applied simply as an average of confidence intervals. This situation demonstrates the necessity of using the system as a means of decision making and not the decision itself.

c. Test Case No. 3

This contract was for the construction of a new applied instruction building in the San Diego area. The estimated construction cost was $280,000 and the A&E contract was negotiated in May 1981.

The scoping estimates for this contract were higher than the negotiated totals. As opposed to test case number two, the regression models generated the larger estimates, while the estimates based on estimated construction cost were the smaller of the two. Again, of all scoping estimates, the methods for computing Section A were the most accurate.

The detailed analysis estimate for grand total fee was within 2% of the negotiated fee. This close estimate is also reflected in each of the three sections as all estimates were accurate. The total for Section A was capped at 6% of estimated construction cost similar to the discussion

in test case number one. The components for Section B totaled within 6% of the negotiated total, while the number of man-days of field investigation was significantly different. There were 27 additional labor hours for Section C, which is reflected in the higher estimate for those services.

D. SUMMARY OF TEST CASES

The effectiveness of the scoping estimates covered all possibilities for these three test cases in that for one contract the estimates were low, another the estimates were high, and another with the estimates very close to the negotiated price. However, the best estimates were predicted for the Section A total. This was expected given the very high r^2 value, .9520, of the regression cost model for Section A. Additionally, the two methods for number of drawings and professional design hours generated reliable estimates.

The detailed analysis method was very accurate for Section A. However, the method tended to estimate a higher number of labor hours. The one component that stood out as different in Section B was the number of man-days of field investigation and detailed analysis method for Section C consistently estimated a higher number of labor hours, similar to Section A. The detailed analysis method was very accurate in estimating the grand total fee with all estimates being within 8% of the negotiated total.

VI. SUMMARY AND CONCLUSIONS

A. SUMMARY

The position of the Department of Defense and Naval Facilities Engineering Command has been established in support of the Brook's Bill method of business for A&E contracting. With the emphasis on procurement of quality construction design through technical competition and negotiation vice obtaining these services through price competition, the responsibility for stewardship of public funds becomes particularly sensitive. While there have been no scandals or investigations of "wrong doings" on the part of the Navy, opponents of the Brook's Bill are keeping a vigil watch on these procurements and practices. As such, it is imperative that established contracting procedures be followed explicitly and executed in an "above reproach" method.

As discussed in Chapter I, the importance of an accurate government estimate in negotiated procurements cannot be overemphasized. Therefore, the motivating idea behind this thesis research was to strengthen the technical competition procurement procedures by developing more effective government estimates. The implementation of this idea was directed towards utilizing the "corporate memory" as a viable resource in developing estimates. There has been an underutilization of this valuable resource due to a lack of an

organized database. Once the database has been constructed, there is seemingly an endless number of analytically derived or retrieved pieces of information available from the data.

B. CONCLUSIONS

The decision process and decision support approach to A&E contract cost estimation is effective. As demonstrated by the test cases, the objectives of this approach were achieved in that estimates which more accurately predicted the negotiated contract cost were derived. Additionally, a greater level of confidence in the accuracy of the estimates was achieved by having the support of a database of empirical information. Other objectives were achieved in that the structure of the decision process provides the means for an organization to use a consistent estimation methodology, pricing information remains current due to the cost index, and relationships between the various components of the fee itemization have been defined for cost estimating.

C. FUTURE RESEARCH

There are many possibilities for future research that can build upon this thesis. The decision process could be refined by the results of a formal questionnaire to the EICs of all Engineering Field Divisions. Accordingly, modifications to the decision process will identify different analytical computations to support the process. The cost

estimation models generated by the multiple regression program could be improved by more detail in the analysis of residuals to determine the descriptive factors of those contracts causing the largest deviations. Different cost indexes could be applied to the cost per unit quantities to determine if cost projections can be improved. Additionally, the research could be expanded by adding more contracts to the database, perhaps to include all Engineering Field Divisions.

APPENDIX A

THE ENGINEERING FIELD DIVISIONS OF NAVFAC

Commanding Officer
Northern Division
Naval Facilities Engineering Command
Philadelphia, PA 19112

Commanding Officer
Chesapeake Division
Naval Facilities Engineering Command
Washington Navy Yard
Washington, DC 20374

Commander
Atlantic Division
Naval Facilities Engineering Command
U.S. Naval Base
Norfolk, VA 23511

Commanding Officer
Southern Division
Naval Facilities Engineering Command
P.O. Box 10068
Charleston, SC 29411

Commanding Officer
Western Division
Naval Facilities Engineering Command
P.O. Box 727
San Bruno, CA 94066

Commander
Pacific Division
Naval Facilities Engineering Command
Pearl Harbor, HI 96860

APPENDIX B

A-E FEE ITEMIZATION
12ND WESTDIV 11012/1 (REV. 6-78)

See Instructions on Reverse

	DATE OF SCOPE OR MODIFICATION	DATE OF ESTIMATE
PROJECT TITLE	CONTRACT NO N62474- -C-	EST. CONSTRUCTION COST
LOCATION	A-E FIRM	

SECTION	ITEM	NO. OF DWGS	PROFESSIONAL			SUB PROFESSIONAL		
			MANHOURS	RATE	COST	MANHOURS	RATE	COST
SECTION A DESIGN	1. PROJECT ENGINEER							
	2. ARCHITECTURAL							
	3. STRUCTURAL							
	4. MECHANICAL							
	5. ELECTRICAL							
	6. CIVIL							
	7. LANDSCAPE							
	8. SPEC/REPORT WRITERS							
	9. TYPIST							
	10. COST ESTIMATOR							
	11. TOTALS							
	12. TOTAL DIRECT LABOR *(Professional and Sub-Professional)*							
	13. OVERHEAD % x $ *(Line 12)*							
	14. TOTAL DIRECT LABOR AND OVERHEAD *(Lines 12+13)*							
	15. PROFIT % x $ *(Line 14)*							
	16. TOTAL FEE FOR DESIGN SERVICES *(Lines 14+15)*							
SECTION B ENGR SVCS, REPRO & TRAVEL	1. SUBSURFACE INVESTIGATION *(Itemized on supplement sheet)*							
	2. TOPOGRAPHIC SURVEY *(Itemized on supplement sheet)*							
	3. FIELD INVESTIGATION *(Itemized on supplement sheet)*							
	4. REPRODUCTION *(Itemized on supplement sheet)*							
	5. OTHER SPECIAL COSTS *(Identified on supplement sheet)*							
	6. TRAVEL - REIMBURSABLE *(Itemized on supplement sheet)*							
	7. TOTAL FEE FOR ENGINEERING SERVICES, REPRODUCTION AND TRAVEL							

SECTION	ITEM	PROFESSIONAL			SUB PROFESSIONAL		
		MANHOURS	RATE	COST	MANHOURS	RATE	COST
SECTION C CONSTR CONTRACT SUPPORT SVCES	1. SHOP DRAWING REVIEW & OFFICE CONSULTATION						
	2. AS-BUILT DRAWING PREPARATION						
	3. TOTAL DIRECT LABOR *(Lines 1 and 2, Professional and Sub-Professional)*						
	4. OVERHEAD % x $ *(Line 3)*						
	5. TOTAL DIRECT LABOR AND OVERHEAD *(Lines 3+4)*						
	6. PROFIT % x $ *(Line 5)*						
	7. TOTAL FEE FOR CONSTRUCTION CONTRACT SUPPORT SERVICES						

GRAND TOTAL FEE DESIGN, ENGINEERING SERVICES, TRAVEL AND CCSS

A-E SIGNATURE	EIC SIGNATURE	CODE	PHONE	CODE OF APPROVAL

SUPPLEMENT TO A-E FEE ITEMIZATION - ENGINEERING SERVICES
12HD WESTDIV 11012/15 (REV. 6-78)

CONTRACT NO.	DATE OF SCOPE OR FEE
N62474- -C-	

Note: *Items 1 and 2 are to include all direct costs, overhead, profit, travel and standard equipment. Items 3, 4, 6 and 7 are to include direct labor cost, overhead and profit.*

1. Sub-Surface Investigation: *Enter total on line 1, Section B of A-E Fee Itemization*

Description	Quantity	Unit Cost	Amount
Mobilization/Demobilization	______	______	$ ______
Borings: Depth ______	______	______	$ ______
Mechanical Analysis	______	______	$ ______
Atterberg Limits	______	______	$ ______
Unconfined Compression	______	______	$ ______
Consolidation Tests	______	______	$ ______
Triaxial Compression	______	______	$ ______
Other	______	______	$ ______
Report	______	______	$ ______
Sub-Total			$ ______
Profit, ______ %			$ ______
Total		Lump Sum	$ ______

2. Topographic Survey: *Enter total on Line 2, Section B of A-E Fee Itemization*

Description			Amount
Survey Party, ______ Man.	______ days	$ ______ per day	$ ______
Survey Party, ______ Man.	______ days	$ ______ per day	$ ______
Computer Time, ______ hrs.		$ ______ per hour	$ ______
Engineering, ______ hrs.		$ ______ per hour	$ ______
Draftsman, ______ hrs.		$ ______ per hour	$ ______
Other, specify			$ ______
Sub-Total			$ ______
Profit, ______ %			$ ______
Total		Lump Sum	$ ______

3. Field Investigation: *Enter total on Line 3, Section B of A-E Fee Itemization*

______ days $ ______ per day Lump Sum $ ______

4. Reproduction: *Enter total on Line 4, Section B of A-E Fee Itemization*

Drawings: ______ sheets or SF/set, ______ submittals. $ ______ per sheet or SF $ ______

Specifications: ______ submittal $ ______ per submittal $ ______

5. Other Special Costs: *Enter total amount on Line 5, Section B, A-E Fee Itemization*

Description	Amount	Description	Amount
Cathodic Soils Testing	$ ______	Feasibility Study	$ ______
Aerial Plan Survey	$ ______	Concept Study	$ ______
Color Renderings	$ ______	Interior Design Package	$ ______
Solar Energy Study	$ ______	Project Engr'ng Documentation	$ ______
Energy Conservation Study	$ ______	Maintenance/Operations Manual	$ ______
Environmental Prot. Plan	$ ______	Other	$ ______
Acoustical Study	$ ______	Lump Sum	______

6. Travel and Subsistence (Reimbursable, in accordance with Government Travel Regulations): *Enter total estimate on Line 6, Section B of A-E Fee Itemization*

Air $ ______ Auto $ ______ Taxi or Car Rental $ ______

Subsistence, Mandays ______ $ ______ per day $ ______

Total Estimated Travel Expense $ ______

7. Options: Field Consultation During Construction, Field Verification Prior to Construction and Value Engineering. *Option to Government, do not enter on A-E Fee Itemization*

Consultation: $ ______ per manday. Verification: $ ______ per manday. VE: $ ______ per manhour.

APPENDIX C

LISTING OF "OTHER SPECIAL COST" ITEMS

Project Engineering Documentation (PED)
Conceptual Studies
Energy Conservation Studies
Solar Energy Studies
Soil Analysis
System Testing
Engineering Studies and Report
Aerial Survey
Photographic Cost
Preparation of 1390/1391
Interior Design Packages
Models
Accoustical Studies
System Cost Estimates
Government Furnished Equipment Coordination
Presentations
Computer Time
Environmental Protection Studies
Economic Analysis
Planning Reports
Lab Analysis
Seismic Studies
Water Analysis
Cathodic Testing/Protection Studies
Operation Manuals
Mail
Structural Analysis
Demolition Phasing Studies
Facility Studies
Screen Photo Mylar
Tank Inspections
System Safety Analysis
Kitchen Consultant
Planimetric Survey
Buoyancy, Lift, Trim Test
Color Sketches
Blast Investigations
Fire Pump Study
Water Pump Study
Program Study
Conferences
Project Support Documentation

APPENDIX D

DATABASE COMPUTER PRINT-OUT

SEQUENCE NUMBER	YEAR	MONTH	OPEN-ENDED CONTRACT	ESTIMATED CONSTRUCTION COST	CATEGORY CODE	WORK CODE	LEAD CODE	NUMBER DRAWINGS	PROFESSIONAL ENGINEER HOURS	SUB-PROFESSIONAL ENGINEER HOURS	SPEC WRITER HOURS	COST ESTIMATOR HOURS
8	75	8	0	580000	1	3	2	35	784	584	40	40

TYPIST HOURS	TOTAL DIRECT LABOR ($)	OVER HEAD RATE	PROFIT RATE	TOTAL DESIGN COST	REPRO COST	TOTAL FEE ENGINEER SERVICES	SHOP DRAW PROF HOURS	SHOP DRAW SUB-PROF HOURS	AS-BUILTS PROF HOURS	AS-BUILTS SUB-PROF HOURS	CONST. CONTRACT SUPPORT	GRAND TOTAL FEE
100	17548	75	10	33780	2082	28522	99	0	30	60	5267	67569

LOCATION CODE	COMPLEXITY CODE	ARCH HRS/DWG	STRU HRS/DWG	MECH HRS/DWG	ELEC HRS/DWG	CIVIL HRS/DWG	LAND HRS/DWG	SUBSURFACE INVESTIGATION	TOPOGRAPHIC SURVEY	FIELD INVESTIGATION
4	5	18	24	23	18	0	0	0	0	8640

ENR BUILDING COST INDEX	SUB-ARCH HRS/DWG	SUB-STRU HRS/DWG	SUB-MECH HRS/DWG	SUB-ELEC HRS/DWG	SUB-CIVIL HRS/DWG	SUB-LAND HRS/DWG	FIELD INVESTIGATION DAYS	TRAVEL COST	PROJECT ENGINEERING DOCUMENTATION
311	18	24	13	18	0	0	40	4800	3000

ARCH DWGS	STRU DWGS	MECH DWGS	ELEC DWGS	CIVIL DWGS	LAND DWGS	CONCEPTUAL STUDY	ENERGY CONSERVATION	SOLAR ENERGY
12	1	12	10	0	0	0	5000	5000

PROJ ENG RATE	ARCH RATE	STRU RATE	MECH RATE	ELEC RATE	CIVIL RATE	LAND RATE	SPEC RATE	COST EST RATE	CONST SUPPORT PROF RATE
17.00	14.00	14.00	14.00	14.00	0.00	0.00	0.00	0.00	14.00

SUB-ARCH RATE	SUB-STRU RATE	SUB-MECH RATE	SUB-ELEC RATE	SUB-CIVIL RATE	SUB-LAND RATE	SUB-SPEC RATE	TYPIST RATE	SUB-COST EST RATE	CONST SUPPORT SUB-PROF RATE
8.00	8.00	8.00	8.00	0.00	0.00	10.00	5.00	10.00	8.00

APPENDIX E

MATRIX OF DESCRIPTIVE FACTORS AND ANALYTICAL COMPUTATIONS

Analytical Computations	Descriptive Factors: Category Code	Number of Disciplines	Range of ECC	Lead Code	Location	Work Code	Date
Section A							
ECC per Drawing	X		X			X	
Cost per Drawing	X		X			X	
Types of Drawings				X			
Hours per Drawing	X	X	X	X		X	
ECC per Labor Hour	X		X			X	
Labor Ratios	X		X	X			
Design Support Hours	X		X				
Overhead		X		X	X		
% of ECC	X		X			X	
Section B							
Sub-Surface Invest.			X			X	
Topographic Survey			X			X	
ECC per Field Invest. Day	X		X			X	
Cost per Field Invest. Day				X	X	X	
Repro. Cost per Drawing					X		
Travel					X		
Other Special Cost			X		X		
% of ECC	X		X			X	

Analytical Computations	Category Code	Number of Disciplines	Range of ECC	Lead Code	Location	Work Code	Date
				Descriptive Factors			
Section C							
Shop Drawings--Pro.	X			X		X	
Shop Drawings--Sub-Pro.	X			X		X	
As-Builts--Pro.	X			X		X	
As-Builts--Sub-Pro.	X			X		X	
% of ECC	X		X	X		X	
Labor Rates					X		X

APPENDIX F

ENGINEERING NEWS RECORD, BUILDING COST INDEX

	Percentage of Contracts	Los Angeles	San Francisco	Seattle
1978				
DEC	2	286	261	279
1979				
MAR	8	281	274	280
JUNE	6	283	274	290
SEPT	10	311	290	306
DEC	11	300	299	300
1980				
MAR	16	303	303	303
JUNE	13	306	313	287
SEPT	14	326	312	325
DEC	9	330	324	328
1981				
MAR	11	327	328	330
APR		327	332	333
MAY		326	332	333
JUNE		326	331	327
JULY		327	336	336
AUG		328	340	347
SEPT		350	340	347
OCT		348	339	346

APPENDIX G

SECTION -A- FINDINGS

Estimated Construction Cost Per Drawing

Limits of Confidence Intervals ($000)

	Category Code		Est. Construction Cost		Work Code	
Codes	Lower	Upper	Lower	Upper	Lower	Upper
0	22.7	44.1	-	-	-	-
1	24.4	37.2	8.6	11.5	26.9	38.1
2	17.7	28.9	13.1	18.1	24.2	33.8
3	-	-	18.2	24.2	22.1	31.5
4	23.9	60.6	24.6	34.3	15.4	21.5
5	4.6	39.9	29.8	39.7	9.7	17.4
6	27.6	59.0	27.5	60.7	-	-
7	17.8	30.1	36.3	62.0	-	-
8	19.3	29.3	40.9	78.1	-	-
9	19.9	40.8	54.4	89.6	-	-

Category Codes: 1--Ops & Trg, 2--Maint & Prod, 4--Supply, 5--Medical, 6--Admin, 7--Community, 8--Utilities, 9--Ground Structures, 0--Family Housing

Estimated Construction Cost: 1--$0 to $50,000, 2--$50,001 to $100,000, 3--$100,001 to $250,000, 4--$250,001 to $500,000, 5--$500,001 to $750,000, 6--$750,001 to $1,000,000, 7--$1,000,001 to $2,500,000, 8--$2,500,001 to $5,000,000, 9--$5,000,001 and up

Work Codes: 1--New Const., 2--Repair, 3--Alteration, 4--Equip. Install., 5--Retrofit

Cost Per Drawing

Limits of Confidence Intervals ($00)

Codes	Category Code Lower	Category Code Upper	Est. Construction Cost Lower	Est. Construction Cost Upper	Work Code Lower	Work Code Upper
0	10.7	17.7	-	-	-	-
1	13.5	18.3	5.0	6.6	13.8	18.3
2	9.6	15.5	7.7	10.7	11.9	15.6
3	-	-	9.6	12.4	11.7	15.8
4	11.7	27.5	13.1	16.4	8.8	12.1
5	3.4	21.6	15.5	19.8	5.4	9.7
6	16.0	28.9	14.9	26.4	-	-
7	9.9	14.3	17.6	29.9	-	-
8	9.7	13.6	15.1	27.9	-	-
9	9.9	19.2	22.8	41.1	-	-

Category Codes: 1--Ops & Trg, 2--Maint & Prod, 4--Supply, 5--Medical, 6--Admin, 7--Community, 8--Utilities, 9--Ground Structures, 0--Family Housing

Estimated Construction Cost: 1--$0 to $50,000, 2--$50,001 to $100,000, 3--$100,001 to $250,000, 4--$250,001 to $500,000, 5--$500,001 to $750,000, 6--$750,001 to $1,000,000, 7--$1,000,001 to $2,500,000, 8--$2,500,001 to $5,000,000, 9--$5,000,001 and up

Work Codes: 1--New Const., 2--Repair, 3--Alteration, 4--Equip. Install., 5--Retrofit

Distribution of Drawings by Discipline

Percentage of Total Drawings

Type of Drawing	Project Engineer	Lead Design Discipline: Architect	Structural	Mechanical	Electrical	Civil	Landscape
Architectural	10	44*	11	8	6	4	14
Structural	32	13	45*	7	5	5	5
Mechanical	12	19	14	60*	7	7	2
Electrical	20	15	16	19	78*	12	2
Civil	13	7	11	4	4	70*	5
Landscape	4	3	2	0	0	3	52*

*The lead discipline determines the distribution of drawings. Example, if the lead discipline is mechanical, then 60% of the total drawings will be mechanical.

Note: If all six types of drawings are not required, the percentages shown can be adjusted to 100%. Example, if the lead discipline is Architectural and only Architectural, Mechanical, and Electrical drawings are required, then the percentages of total drawings for the required types of drawings are computed as follows:

Architectural Drawings = 44 ÷ (44 + 19 + 15)
Mechanical Drawings = 19 ÷ (44 + 19 + 15)
Electrical Drawings = 15 ÷ (44 + 19 + 15)

Average Hours Per Drawing by Category Codes

	All Contracts*	Category Codes** 0	1	2	4	5	6	7	8	9
PROJECT ENGINEER	3-5	4	4	4	9	2	4	3	3	5
ARCHITECT	13-17	17	18	15	20	10	26	12	10	5
SUB-ARCH	24-30	30	31	26	32	21	39	27	16	30
STRUCTURAL	18-24	14	22	24	20	22	34	18	21	12
SUB-STRUCT	26-32	23	27	29	32	28	34	27	30	28
MECHANICAL	13-17	18	17	15	16	13	26	13	13	--
SUB-MECH	21-25	22	26	20	30	25	29	25	20	--
ELECTRICAL	13-17	22	17	16	19	8	24	12	13	12
SUB-ELEC	21-25	21	27	23	28	17	32	22	21	28
CIVIL	14-18	15	17	19	22	--	23	15	15	15
SUB-CIVIL	23-29	28	27	29	37	--	35	26	19	20
LANDSCAPE	15-23	19	21	14	27	--	23	20	7	--
SUB-LAND	23-33	24	34	23	24	--	29	28	20	--
TOTAL DESIGN	38-44	43	46	38	52	33	68	38	36	40
SPEC WRITER	4-6	5	6	4	10	5	8	4	4	6
COST ESTIMATOR	3-5	4	4	3	5	3	6	3	3	4
TYPIST	3-5	4	5	4	7	5	5	4	4	5
TOTAL DESIGN SUPPORT	10-13	13	14	11	22	11	19	12	9	14
TOTAL PROFESSIONAL	23-29	29	30	25	39	20	46	22	22	29
TOTAL SUB-PROF	25-29	27	30	24	34	24	41	28	23	25
TOTAL	50-57	56	60	49	74	44	87	50	46	54

*A 95% Confidence Interval

**1--Operational & Training, 2--Maintenance & Production, 4--Supply, 5--Medical, 6--Administrative, 7--Community, 8--Utilities, 9--Ground Structures, 0--Family Housing

--Data not available

Average Hours Per Drawing
by Estimated Construction Cost

	All Contracts*	Estimated Construction Cost** 1	2	3	4	5	6	7	8	9
PROJECT ENTINEER	3-5	2	2	3	5	6	6	7	4	5
ARCHITECT	13-17	6	8	9	12	21	21	24	23	42
SUB-ARCH	24-30	9	17	21	26	31	38	40	41	59
STRUCTURAL	18-24	9	12	14	18	22	24	31	29	46
SUB-STRUCT	26-32	14	16	21	28	30	32	38	32	45
MECHANICAL	13-17	5	10	9	16	17	25	25	20	34
SUB-MECH	21-25	13	17	17	25	27	28	31	34	43
ELECTRICAL	13-17	7	7	12	15	17	22	25	23	33
SUB-ELEC	21-25	13	14	21	24	25	27	30	38	42
CIVIL	14-18	7	12	14	14	16	19	22	24	33
SUB-CIVIL	23-29	11	11	21	26	29	24	35	35	47
LANDSCAPE	15-23	--	--	15	16	15	14	20	29	29
SUB-LAND	23-33	--	--	25	21	26	29	28	27	37
TOTAL DESIGN	38-44	18	27	33	44	51	60	71	64	96
SPEC WRITER	4-6	3	4	5	6	6	7	7	6	6
COST ESTIMATOR	3-5	2	3	4	4	4	6	4	4	6
TYPIST	3-5	4	4	4	5	5	4	4	3	3
TOTAL DESIGN SUPPORT	10-13	8	10	12	14	15	15	15	13	14
TOTAL PROFESSIONAL	23-29	12	18	21	28	35	40	45	36	56
TOTAL SUB-PROF	25-29	14	19	24	30	31	35	41	41	54
TOTAL	50-57	26	37	45	58	66	75	86	77	110

*A 95% Confidence Interval

**1--Up to $50,000, 2--$50,001 to $100,000, 3--$100,001 to $250,000, 4--$250,001 to $500,000, 5--$500,001 to $750,000, 6--$750,001 to $1,000,000, 7--$1,000,001 to $2,500,000, 8--$2,500,001 to $5,000,000, 9--$5,000,001 and up

--Data not available

Average Hours Per Drawing
by Lead Discipline Code

	All Contracts*	Lead Codes** 1	2	3	4	5	6	7
PROJECT ENGINEER	3-5	11	3	7	4	3	4	6
ARCHITECT	13-17	18	15	10	13	15	23	19
SUB-ARCH	24-30	33	29	25	20	20	40	20
STRUCTURAL	18-24	10	20	26	26	19	15	22
SUB-STRUCT	26-32	35	28	29	34	26	26	--
MECHANICAL	13-17	15	14	22	14	22	15	21
SUB-MECH	21-25	30	24	29	21	27	24	--
ELECTRICAL	13-17	13	15	21	15	15	14	15
SUB-ELEC	21-25	30	23	27	22	23	21	--
CIVIL	14-18	18	17	13	22	21	13	30
SUB-CIVIL	23-29	28	30	22	27	25	21	12
LANDSCAPE	15-23	5	21	20	26	--	17	9
SUB-LAND	23-33	10	29	28	26	--	23	28
TOTAL DESIGN	38-44	31	43	54	36	41	38	38
SPEC WRITER	4-6	8	5	8	5	5	5	4
COST ESTIMATOR	3-5	3	4	5	3	3	4	5
TYPIST	3-5	6	4	5	4	4	4	2
TOTAL DESIGN SUPPORT	10-13	17	13	18	10	12	13	10
TOTAL PROFESSIONAL	23-29	32	26	41	23	27	26	24
TOTAL SUB-PROF	25-29	16	30	31	23	27	25	24
TOTAL	50-57	48	55	72	46	54	51	48

*A 95% Confidence Interval

**1--Project Engineer, 2--Architect, 3--Structural, 4--Mechanical, 5--Electrical, 6--Civil, 7--Landscape

--Data not available

Average Hours Per Drawing by Work Codes

	All Contracts*	Work Codes** 1	2	3	4	5
PROJECT ENGINEER	3-5	4	4	4	2	2
ARCHITECT	13-17	19	13	13	13	7
SUB-ARCH	24-30	33	23	26	27	16
STRUCTURAL	18-24	25	15	20	23	16
SUB-STRUCT	26-32	32	23	28	11	23
MECHANICAL	13-17	17	15	17	12	7
SUB-MECH	21-25	26	21	26	17	13
ELECTRICAL	13-17	17	14	15	12	11
SUB-ELEC	21-25	27	19	24	15	18
CIVIL	14-18	18	14	16	17	22
SUB-CIVIL	23-29	29	22	27	11	19
LANDSCAPE	15-23	21	17	13	35	--
SUB-LAND	23-33	30	24	19	30	--
TOTAL DESIGN	38-44	49	39	42	30	23
SPEC WRITER	4-6	6	5	5	4	3
COST ESTIMATOR	3-5	4	4	4	2	2
TYPIST	3-5	4	5	4	5	3
TOTAL DESIGN SUPPORT	10-13	13	13	13	10	7
TOTAL PROFESSIONAL	23-29	31	26	27	19	14
TOTAL SUB-PROF	25-29	32	26	28	20	16
TOTAL	50-57	62	52	55	40	30

*A 95% Confidence Interval

**1--New Construction, 2--Repair, 3--Alteration, 4--Equipment Installation, 5--Retrofit

--Data not available

Average Hours Per Drawing
by Number of Design Desciplines

	All Contracts*	Number of Design Disciplines 1	2	3	4	5	6	7
PROJECT ENGINEER	3-5	--	4	5	4	3	5	3
ARCHITECT	13-17	--	10	8	9	15	19	19
SUB-ARCH	24-30	--	21	17	19	27	34	34
STRUCTURAL	18-24	15	21	19	24	18	25	21
SUB-STRUCT	26-32	20	21	34	35	23	31	30
MECHANICAL	13-17	4	13	11	16	14	19	17
SUB-MECH	21-25	8	17	16	26	20	29	29
ELECTRICAL	13-17	10	11	11	14	16	20	17
SUB-ELEC	21-25	24	18	20	22	21	27	29
CIVIL	14-18	12	12	16	15	14	19	18
SUB-CIVIL	23-29	24	18	22	23	24	27	31
LANDSCAPE	15-23	--	7	24	14	19	24	19
SUB-LAND	23-33	--	20	32	18	43	31	27
TOTAL DESIGN	38-44	25	35	36	40	41	53	52
SPEC WRITER	4-6	2	5	5	4	5	7	6
COST ESTIMATOR	3-5	2	4	3	3	4	4	5
TYPIST	3-5	4	5	4	4	4	4	4
TOTAL DESIGN SUPPORT	10-13	8	13	11	11	12	15	14
TOTAL PROFESSIONAL	23-29	12	24	24	24	26	35	31
TOTAL SUB-PROF	25-29	20	24	23	26	27	33	35
TOTAL	50-57	32	48	47	50	53	68	66

*A 95% Confidence Interval

--Data not available

Estimated Construction Cost Per Total Labor Hour

Limits of Confidence Intervals ($)

Codes	Category Code Lower	Category Code Upper	Est. Construction Cost Lower	Est. Construction Cost Upper	Work Code Lower	Work Code Upper
0	410	796	-	-	-	-
1	437	511	357	396	455	526
2	435	494	402	444	472	563
3	-	-	434	493	435	499
4	446	623	453	534	380	509
5	322	541	485	538	399	472
6	392	577	462	631	-	-
7	403	482	506	609	-	-
8	453	536	519	1162	-	-
9	456	609	481	860	-	-

Category Codes: 1--Ops & Trg, 2--Maint & Prod, 4--Supply, 5--Medical, 6--Admin, 7--Community, 8--Utilities, 9--Ground Structures, 0--Family Housing

Estimated Construction Cost: 1--$0 to $50,000, 2--$50,001 to $100,000, 3--$100,001 to $250,000, 4--$250,001 to $500,000, 5--$500,000 to $750,000, 6--$750,001 to $1,000,000, 7--$1,000,001 to $2,500,000, 8--$2,500,001 to $5,000,000, 9--$5,000,001 and up

Work Codes: 1--New Const., 2--Repair, 3--Alteration, 4--Equip. Install., 5--Retrofit

Estimated Construction Cost Per Design Hour

Limits of Confidence Intervals ($)

	Category Code		Est. Construction Cost		Work Code	
Codes	Lower	Upper	Lower	Upper	Lower	Upper
0	546	985	-	-	-	-
1	585	694	500	613	590	673
2	579	692	547	651	642	767
3	-	-	593	700	587	680
4	628	914	597	720	476	732
5	440	725	627	697	533	668
6	532	733	583	810	-	-
7	548	656	603	746	-	-
8	583	688	639	1346	-	-
9	621	920	555	988	-	-

Category Codes: 1--Ops & Trg, 2--Main & Prod, 4--Supply, 5--Medical, 6--Admin, 7--Community, 8--Utilities, 9--Ground Structures, 0--Family Housing

Estimated Construction Cost: 1--$0 to $50,000, 2--$50,001 to $100,000, 3--$100,001 to $250,000, 4--$250,001 to $500,000, 5--$500,001 to $750,000, 6--$750,001 to $1,000,000, 7--$1,000,001 to $2,500,000, 8--$2,500,001 to $5,000,000, 9--$5,000,001 and up

Work Codes: 1--New Const., 2--Repair, 3--Alteration, 4--Equip. Install., 5--Retrofit

SECTION A % of Estimated Construction Cost

Limits of Confidence Intervals (%)

Codes	Category Code Lower	Category Code Upper	Est. Construction Cost Lower	Est. Construction Cost Upper	Work Code Lower	Work Code Upper
0	4.15	5.60	-	-	-	-
1	5.36	5.75	5.88	5.95	5.2	5.6
2	5.38	5.72	5.83	5.93	5.08	5.6
3	-	-	5.19	5.64	5.22	5.58
4	4.54	5.62	5.11	5.53	5.47	6.00
5	5.66	6.00	4.99	5.36	5.46	5.86
6	4.83	5.93	4.7	5.64	-	-
7	5.24	5.70	4.61	5.12	-	-
8	5.11	5.52	2.95	4.90	-	-
9	4.94	5.29	3.82	5.01	-	-

Category Codes: 1--Ops & Trg, 2--Maint & Prod, 4--Supply, 5--Medical, 6--Admin, 7--Community, 8--Utilities, 9--Ground Structures, 0--Family Housing

Estimated Construction Cost: 1--$0 to $50,000, 2--$50,001 to $100,000, 3--$100,001 to $250,000, 4--$250,001 to $500,000, 5--$500,001 to $750,000, 6--$750,001 to $1,000,000, 7--$1,000,001 to $2,500,000, 8--$2,500,001 to $5,000,000, 9--$5,000,001 and up

Work Codes: 1--New Const., 2--Repair, 3--Alteration, 4--Equip. Install., 5--Retrofit

APPENDIX H

SECTION -B- FINDINGS

Sub-Surface Investigation

Codes	Estimated Construction Cost			Work Code		
	Lower	Upper	% of ECC	Lower	Upper	% of ECC
1	*	*	2.8	3250	4071	0.6
2	1334	2345	2.0	1119	4546	1.2
3	999	3431	1.1	1956	6117	1.0
4	2319	4297	0.9	*	*	0.2
5	850	3693	0.3	*	*	0.5
6	2543	6803	0.5	-	-	-
7	2351	8407	0.4	-	-	-
8	2019	8265	0.2	-	-	-
9	4071	10486	0.1	-	-	-

Estimated Construction Cost: 1--$0 to $50,000, 2--$50,001 to $100,000, 3--$100,001 to $250,000, 4--$250,001 to $500,000, 5--$500,001 to $750,000, 6--$750,001 to $1,000,000, 7--$1,000,001 to $2,500,000, 8--$2,500,001 to $5,000,000, 9--$5,000,001 and up

Work Codes: 1--New Const., 2--Repair, 3--Alteration, 4--Equip. Install., 5--Retrofit

*Insufficient data to construct confidence interval

Topographic Survey

Limits of Confidence Intervals ($)

Codes	Estimated Construction Cost Lower	Upper	% of ECC	Work Code Lower	Upper	% of ECC
1	762	2806	7.9	2533	3715	0.9
2	1158	4212	3.4	3432	8444	2.3
3	563	6272	2.0	2530	5139	1.6
4	2405	3817	0.9	*	*	6.9
5	323	12486	1.0	*	*	0.4
6	2506	5996	0.5	-	-	-
7	2348	8460	0.4	-	-	-
8	3296	8588	0.2	-	-	-
9	1183	9570	0.1	-	-	-

Estimated Construction Cost: 1--$0 to $50,000, 2--$50,001 to $100,000, 3--$100,001 to $250,000, 4--$250,001 to $500,000, 5--$500,001 to $750,000, 6--$750,001 to $1,000,000, 7--$1,000,001 to $2,500,000, 8--$2,500,001 to $5,000,000, 9--$5,000,001 and up

Work Codes: 1--New Const., 2--Repair, 3--Alteration, 4--Equip. Install., 5--Retrofit

*Insufficient data to construct confidence interval

Estimated Construction Cost Per

Man-Day of Field Investigation

Limits of Confidence Intervals ($000)

Codes	Category Code Lower	Category Code Upper	Est. Construction Cost Lower	Est. Construction Cost Upper	Work Code Lower	Work Code Upper
0	9.0	41.9	-	-	-	-
1	37.2	73.0	6.7	13.2	70.1	116.6
2	0.0	203.7	10.8	18.8	22.6	34.5
3	-	-	19.7	28.4	15.9	146.3
4	32.3	133.4	35.2	46.6	7.3	28.1
5	12.2	33.1	38.5	68.3	10.5	22.3
6	63.9	405.5	60.4	96.8	-	-
7	22.9	110.5	28.4	415.9	-	-
8	20.3	36.5	68.4	426.7	-	-
9	32.5	63.9	155.4	485.9	-	-

Category Codes: 1--Ops & Trg, 2--Maint & Prod, 4--Supply, 5--Medical, 6--Admin, 7--Community, 8--Utilities, 9--Ground Structures, 0--Family Housing

Estimated Construction Cost: 1--$0 to $50,000, 2--$50,001 to $100,000, 3--$100,001 to $250,000, 4--$250,001 to $500,000, 5--$500,001 to $750,000, 6--$750,001 to $1,000,000, 7--$1,000,001 to $2,500,000, 8--$2,500,001 to $500,000, 9--$5,000,001 and up

Work Codes: 1--New Const., 2--Repair, 3--Alteration, 4--Equip. Install., 5--Retrofit

SECTION B % of Estimated Construction Code

Limits of Confidenct Intervals

Codes	Category Code Lower	Category Code Upper	Est. Construction Cost Lower	Est. Construction Cost Upper	Work Code Lower	Work Code Upper
0	1.9	3.9	-	-	-	-
1	3.1	4.6	5.4	8.7	2.7	4.0
2	2.6	4.4	4.0	5.6	3.4	5.6
3	-	-	2.8	5.8	2.8	4.2
4	1.2	3.5	2.6	3.4	2.1	6.5
5	1.7	4.5	1.9	3.8	3.5	6.1
6	.9	2.9	1.8	3.8	-	-
7	2.9	4.5	1.4	2.7	-	-
8	3.2	5.7	1.0	1.7	-	-
9	3.7	9.7	0.5	1.2	-	-

Category Codes: 1--Ops & Trg, 2--Maint & Prod, 4--Supply, 5--Medical, 6--Admin, 7--Community, 8--Utilities, 9--Ground Structures, 0--Family Housing

Estimated Construction Cost: 1--$0 to $50,000, 2--$50,001 to $100,000, 3--$100,001 to $250,000, 4--$250,001 to $500,000, 5--$500,001 to $750,000, 6--$750,001 to $1,000,000, 7--$1,000,001 to $2,500,000, 8--$2,500,001 to $500,000, 9--$5,000,001 and up

Work Codes: 1--New Const., 2--Repair, 3--Alteration, 4--Equip Install., 5--Retrofit

APPENDIX I

SECTION C FINDINGS

Section C % of Estimated Construction Cost

Limits of Confidence Intervals (%)

Codes	Category Codes Lower	Category Codes Upper	Lead Code Lower	Lead Code Upper	Work Code Lower	Work Code Upper	Average % of ECC
0	.4	1.0	-	-	-	-	-
1	.8	1.1	-	-	.7	1.1	1.6
2	.8	1.2	.9	1.1	.8	1.0	1.1
3	-	-	.7	1.3	.9	1.1	1.0
4	.5	1.1	.9	1.1	.5	1.1	.7
5	.5	1.9	.6	.8	.9	1.4	.6
6	.6	1.0	.7	1.2	-	-	.8
7	.6	1.6	-	-	-	-	.5
8	.7	1.1	-	-	-	-	.4
9	.4	1.2	-	-	-	-	.5

Lead Code: 2--Architect, 3--Structural, 4--Mechanical, 5--Electrical, 6--Civil

Category Codes: 1--Ops & Trg, 2--Maint & Prod, 4--Supply, 5--Medical, 6--Admin, 7--Community, 8--Utilities, 9--Ground Structures, 0--Family Housing

Estimated Construction Cost: 1--$0 to $50,000, 2--$50,001 to $100,000, 3--$100,001 to $250,000, 4--$250,001 to $500,000, 5--$500,001 to $750,000, 6--$750,001 to $1,000,000, 7--$1,000,001 to $2,500,000, 8--$2,500,001 to $5,000,000, 9--$5,000,001 and up

Work Codes: 1--New Const., 2--Repair, 3--Alteration, 4--Equip. Install., 5--Retrofit

APPENDIX J

LABOR RATES

	Average Labor Rates ($)				
	Calendar Year			Percentage Increase	
	1979	1980	1981	1979-1980	1980-1981*
Professional					
Project Engineer	16.39	17.79	18.54	8.5	4.2
Architect	13.53	14.49	14.78	7.1	2.1
Structural	13.86	14.83	15.72	6.9	6.0
Mechanical	13.74	14.57	15.36	6.0	5.4
Electrical	13.48	14.63	15.64	8.5	6.9
Civil	13.21	14.37	14.87	8.2	3.5
Landscape	12.45	14.89	14.96	19.6	.5
Spec. Writer	13.02	14.12	15.26	8.4	8.1
Cost Estimator	12.97	14.17	15.20	9.3	7.3
CCSS Rate	14.02	14.82	16.05	5.7	8.3
Sub-Professional					
Architect	8.61	8.91	9.28	3.5	4.2
Structural	8.87	9.07	10.28	2.3	13.3
Mechanical	8.91	8.97	9.38	.7	4.6
Electrical	8.69	8.88	9.55	2.2	7.5
Civil	8.57	9.47	9.39	10.5	- .2
Landscape	7.81	8.75	8.89	12.0	1.6
Spec. Writer	8.20	8.09	8.21	- 1.3	1.5
Typist	5.94	6.62	6.84	11.4	3.3
Cost Estimator	8.77	8.24	9.18	- 6.0	11.4
CCSS Rate	9.00	9.13	9.98	1.4	9.3

*Through the first six months of 1981

Labor Rates

Average Labor Rates by Location, 1979-1981 ($)

	All Contracts	Location Code* 1	2	3	4	5	6
Professional							
Project Engineer	17.41	19.75	17.90	17.67	17.07	17.19	13.63
Architect	14.21	16.82	13.52	13.84	14.48	14.29	12.25
Structural	14.60	15.75	14.54	14.68	14.79	14.52	10.47
Mechanical	14.40	17.21	13.73	14.53	14.59	14.26	11.38
Electrical	14.36	16.75	14.46	14.06	14.76	14.16	11.08
Civil	14.05	14.89	13.20	14.85	14.43	13.81	10.77
Landscape	14.23	-	12.43	16.40	14.60	14.45	10.50
Spec. Writer	13.92	15.90	13.99	14.17	13.65	13.92	10.51
Cost Estimator	13.92	16.58	13.42	13.82	13.70	14.32	10.56
CCSS Rate	14.74	16.89	14.99	14.85	14.47	14.74	10.79

*1--Adak, 2--Washington/Oregon, 3--No. California (S.F. Area), 4--Los Angeles Area, 5--San Diego Area, 6--Yuma, Arizona

	All Contracts	Location Code* 1	2	3	4	5	6
Sub-Professional							
Architect	8.87	10.36	8.57	8.56	9.15	8.83	7.34
Structural	9.20	9.60	8.59	9.28	9.72	9.07	7.63
Mechanical	9.01	10.36	8.75	8.66	9.40	8.98	8.03
Electrical	8.91	10.44	8.93	8.48	9.25	8.80	7.93
Civil	9.15	10.43	7.99	9.65	9.75	8.72	7.70
Landscape	8.55	8.50	8.23	8.58	9.23	8.19	-
Spec. Writer	8.14	7.67	7.28	9.92	8.69	7.52	7.54
Typist	6.43	7.45	6.35	6.69	6.33	6.27	5.33
Cost Estimator	8.56	8.36	8.44	8.99	9.73	7.93	6.97
CCSS Rate	9.21	10.22	8.77	9.19	9.48	9.13	7.38

*1--Adak, 2--Washington/Oregon, 3--No. California (S.F. Area), 4--Los Angeles Area, 5--San Diego Area, 6--Yuma, Arizona

APPENDIX K

COST ESTIMATION WORKSHEET

PROJECT TITLE: ______________________________

ESTIMATED CONSTRUCTION COST: $ ______________________________

LOCATION: ______________________________

DATE: ______________________________

ENR BCI: ______________________________

CATEGORY CODE: ______________________________

WORK CODE: ______________________________

LEAD DISCIPLINE CODE: ______________________________

NUMBER OF DISCIPLINES: ______________________________

I. GRAND TOTAL FEE (GTF)

Estimated Construction Cost (ECC): $ ________________

Number of Design Disciplines (NDD): ________________

$$\underset{\text{GTF}}{\$\underline{\qquad\qquad}} = -3965.6 + .0532(\$\underset{\text{ECC}}{\qquad\qquad}) + 3985.3(\underset{\text{NDD}}{\qquad\qquad})$$

II. COST ADJUSTMENT (CA)

CA = Current ENR BCI ÷ Database ENR BCI

= ________ ÷ 303 = ________

III. SECTION A (SEC A)

A. Number of Drawings (ND)

1. <u>Regression Model</u>

$$\underset{ND}{\underline{\qquad}} = 1.14 + .000014(\underset{ECC}{\qquad}) + 2.13(\underset{NDD}{\qquad})$$

2. <u>Estimated Construction Cost per Drawing (APPENDIX G)</u>

		Confidence Intervals ($)	
		Lower	Upper
Category Code	______	$______	$______
ECC Code	______	$______	$______
Work Code	______	$______	$______
Database		$24,946	$30,155

ECC/Drawing = $__________

$$\underset{ND}{\underline{\qquad}} = (\underset{\text{Project ECC}}{\qquad}) \div (\underset{\text{ECC/Drawing}}{\qquad} \times \underset{CA}{\qquad})$$

B. Scoping Estimates

1. Regression Model

$\underset{\text{SEC A}}{\$\_\_\_\_\_\_} = -3804 + .0421(\underset{\text{ECC}}{\$\qquad\qquad}) + 1788.4(\underset{\text{NDD}}{\qquad})$

2. <u>Cost per Drawing (APPENDIX G)</u>

		Confidence Intervals ($)	
		Lower	Upper
Category Code	______	$ _____	$ _____
ECC Code	______	$ _____	$ _____
Work Code	______	$ _____	$ _____
Database		$1,263	$1,476

Cost/Drawing = $ __________

$\underset{\text{SEC A}}{\$\_\_\_\_\_\_} = (\underset{\text{ND}}{\qquad}) \times (\underset{\text{Cost/Drawing}}{\qquad\qquad} \times \underset{\text{CA}}{\qquad})$

3. Percentage of Estimated Construction Cost (APPENDIX G)

		Confidence Interval (%)	
		Lower	Upper
Category Code	______	____%	____%
ECC Code	______	____%	____%
Work Code	______	____%	____%
Database		5.29%	5.48%

ECC % = __________

$\underset{\text{SEC A}}{\$\_\_\_\_\_\_\_\_} = (\underset{\text{ECC}}{\$\qquad\qquad}) \times (\underset{\text{ECC \%}}{\qquad\qquad} \div 100)$

C. Detailed Analysis

1. Distribution of Drawings (APPENDIX G)

Type of Drawing		Lead Code % of Total		Total Number of Drawings		
Architectural	=	( )	x	( )	=	________
Structural	=	( )	x	( )	=	________
Mechanical	=	( )	x	( )	=	________
Electrical	=	( )	x	( )	=	________
Civil	=	( )	x	( )	=	________
Landscape	=	( )	x	( )	=	________

2. Hours per Drawing (APPENDIX G)

	Complete Database	CAT	ECC	LEAD	WORK	DIS	Computed Average
Project Engineer	3-5						
Architect	13-17						
Sub-Arch	24-30						
Structural	18-24						
Sub-Struct	26-32						
Mechanical	13-17						
Sub-Mech	21-25						
Electrical	13-17						
Sub-Elect	21-25						
Civil	14-18						
Sub-Civil	23-29						
Landscape	15-23						
Sub-Land	23-33						
Total Design	38-44						
Spec Writer	4-6						
Cost Estimator	3-5						
Typist	3-5						
Total Design Support	10-13						
Total Professional	23-29						
Total Sub-Prof	25-29						
Total	50-57						

3. <u>Total Labor Hours</u> (TLH)

Estimated Construction Cost per Total Labor Hour (APPENDIX G)

		Confidence Interval ($)	
		<u>Lower</u>	<u>Upper</u>
Category Code	_____	$ _____	$ _____
ECC Code	_____	$ _____	$ _____
Work Code	_____	$ _____	$ _____
Database		$ 466	$ 505

ECC/Total Labor Hour = __________

_____ = ($) ÷ (x   )
TLH   ECC   ECC/Total Labor Hours   CA

4. <u>Total Design Hours (Professional & Subprofessional</u> (TDH)

Estimated Construction Cost per Total Design Hour (APPENDIX G)

		Confidence Interval ($)	
		<u>Lower</u>	<u>Upper</u>
Category Code	_____	$ _____	$ _____
ECC Code	_____	$ _____	$ _____
Work Code	_____	$ _____	$ _____
Database		$ 625	$ 680

ECC/Total Design Hour = __________

____ = ($) ÷ (x   )
TLH   ECC   ECC/Total Design Hours   CA

5. <u>Professional Design Hours</u> (PDH)

- Regression Model

$$\underset{\text{PDH}}{\underline{\qquad}} = -17.7 + .0006(\$ \underset{\text{ECC}}{\qquad\qquad}) + 10.7(\underset{\text{NDD}}{\quad})$$

6. <u>Labor Ratios</u>

   a. Design Hours--Professional & Subprofessional

   Professional Design Hours (PDH)

$$\underset{\text{PDH}}{\underline{\quad}} = \underset{\text{Total Design Hours(TDH)}}{\underline{\qquad\qquad\qquad}} \times (\underline{\quad}\% \div 100)$$

Database:	42% to 46%
Lead Code 3 (STRUCT):	46% to 59%

   Subprofessional Design Hours (SDH)

$$\underset{\text{SDH}}{\underline{\quad}} = \underset{\text{Total Design Hours(TDH)}}{\underline{\qquad\qquad\qquad}} \times (\underline{\quad}\% \div 100)$$

Database:	54% to 58%
Lead Code 3 (STRUCT):	41% to 54%

b. Total Hours--Professional & Subprofessional

Total Professional Hours (TPH)

$$\frac{\_\_\_}{TPH} = \frac{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_}{\text{Total Labor Hours (TLH)}} \times (\_\_\_\_\% \div 100)$$

Database: 48% to 50%

Lead Code 3 (STRUCT): 52% to 62%

Total Subprofessional Hours (TSH)

$$\frac{\_\_\_}{TSH} = \frac{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_}{\text{Total Labor Hours (TLH)}} \times (\_\_\_\_\% \div 100)$$

Database: 50% to 52%

Lead Code 3 (STRUCT): 38% to 48%

c. Total Hours--Design & Design Support

Total Design Hours (TDH)

$$\frac{\_\_\_}{TDH} = \frac{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_}{\text{Total Labor Hours (TLH)}} \times (\_\_\_\_\% \div 100)$$

Database: 80% to 82%

ECC under $50,000: 67% to 76%

ECC over $5,000,000: 82% to 92%

Total Design Support Hours (TDSH)

$$\frac{\_\_\_\_}{TDSH} = \frac{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_}{\text{Total Labor Hours (TLH)}} \times (\_\_\_\_\% \div 100)$$

Database: 18% to 20%

ECC under $50,000: 24% to 33%

ECC over $5,000,000: 8% to 18%

7. <u>Design Support Hours</u>

a. Specifications Writer Hours

$$\frac{\rule{2em}{0.4pt}}{\text{SWH}} = \frac{\rule{16em}{0.4pt}}{\text{Professional Design Hours (PDH)}} \div \rule{4em}{0.4pt}$$

Database:	4 to 6
ECC over $1,000,000:	6 to 10

b. Cost Estimator Hours (CEH)

$$\frac{\rule{2em}{0.4pt}}{\text{CEH}} = \frac{\rule{16em}{0.4pt}}{\text{Professional Design Hours (PDH)}} \div \rule{4em}{0.4pt}$$

Database:	5 to 7
ECC under $50,000:	3 to 5
ECC over $1,000,000:	8 to 12

c. Typist Hours (TH)

$$\frac{\rule{2em}{0.4pt}}{\text{TH}} = \frac{\rule{16em}{0.4pt}}{\text{Professional Design Hours (PDH)}} \div \rule{4em}{0.4pt}$$

Database:	5 to 7
ECC under $250,000:	3 to 5
ECC over $5,000,000:	7 to 30

For ECC under $750,000:

$$\frac{\rule{3em}{0.4pt}}{\text{TH}} = \frac{\rule{14em}{0.4pt}}{\text{Specification Writer Hours}}$$

For ECC over $750,000:

$$\frac{\rule{3em}{0.4pt}}{\text{TH}} = \frac{\rule{14em}{0.4pt}}{\text{Specification Writer Hours}} \div 2$$

8. Overhead

Database:	102% to 106%
No. of Disciplines--1:	90% to 100%
Location--Adak:	105% to 130%
Lead--Structural:	105% to 126%
--Civil:	110% to 124%

9. Profit

Database:	10%
Lead--Project Engineer:	11%
--Structural:	11%

IV. SECTION B (SEC B)

A. Scoping Estimates

1. Regression Model

$$\$\underset{\text{SEC B}}{\underline{\quad\quad}} = -60.7 + .0092(\$\underset{\text{ECC}}{\quad\quad\quad\quad}) + 1842.3(\underset{\text{NDD}}{\quad\quad})$$

2. Percentage of Estimated Construction Cost (APPENDIX H)

		Confidence Interval (%)	
		Lower	Upper
Category Code	_____	_____%	_____%
ECC Code	_____	_____%	_____%
Work Code	_____	_____%	_____%
Database		3.46%	4.37%

ECC % = __________

$$\$\underset{\text{SEC B}}{\underline{\quad\quad\quad}} = (\$\underset{\text{ECC}}{\quad\quad\quad\quad}) \times (\underset{\text{ECC \%}}{\quad\quad\quad} \div 100)$$

B. Detailed Analysis

1. Subsurface Investigation (SI) (APPENDIX H)

		Confidence Interval ($)	
		Lower	Upper
ECC Code	________	$ ________	$ ________
Work Code	________	$ ________	$ ________
Database		$3,195	$4,528

Computed Average = $ ____________

$ ______________ = ________________ x ______________
SI Computed Average CA

2. Topographic Survey (TS) (APPENDIX H)

		Confidence Interval ($)	
		Lower	Upper
ECC Code	________	$ ________	$ ________
Work Code	________	$ ________	$ ________
Database		$3,252	$4,735

Computed Average = $ ____________

$ ______________ = ________________ x ______________
TS Computed Average CA

3. <u>Field Investigation</u> (FI)

a. Number of Man-Days (NM)

Estimated Construction Cost per Man-Day (APPENDIX H)

		Confidence Interval ($)	
		Lower	Upper
Category Code	____	$ ______	$ ______
ECC Code	____	$ ______	$ ______
Work Code	____	$ ______	$ ______
Database		$41,766	$77,047

ECC/Man-Day = $ __________

____ = ($ ECC) ÷ ($ ECC/Man-Day x CA)
NM

b. Cost per Man-Day

Database:	$258 to $283
Location--Adak:	$222 to $718
--Yuma:	$202 to $258
Lead--Project Engineer:	$280 to $434

Computed Average = $ __________

________ = ($ Computed Average) x (CA)
CM

c. Total for Field Investigation

$ ________ = ________ x $ ________
FI NM CM

4. <u>Reproduction (RP)</u>

a. Cost per Drawing (CPD)

Database:	\$63 to \$74
Location--Adak:	\$61 to \$115
--Wash/Oregon:	\$60 to \$67

Computed Average = \$ ________

________ = ________ x ________
CPD Computed Average CA

b. Total for Reproduction

\$ ________ = \$ ________ x ________
RP CPD Number of Drawings (ND)

5. <u>Other Special Cost</u>

a. Project Engineering Documentation (PED)

(1) Total Amount

Database Confidence Interval

\$2,688 to \$3,735

Selected Total: \$ ________

\$ ________ = \$ ________ x ________
PED Selected Total CA

(2) Percentage of ECC

Database Confidence Interval

0.42% to 0.77%

Selected % = ________

\$ ________ = (\$ ________) x (________ ÷ 100)
PED ECC Selected %

b. Conceptual Studies (CS)

(1) Total Amount

Database Confidence Interval

$5,851 to $13,476

Selected Total = $ ________________

$ ________ = $ ____________ x ________
CS Selected Total CA

(2) Percentage of ECC

Database Confidence Interval

0.55% to 1.04%

Selected % = ____________________

$ _____ = ($) x (÷ 100)
CS ECC Selected %

c. Energy Conservation Studies (ECS)

(1) Total Amount

Database Confidence Interval

$2,892 to $5,005

Selected Total = $ ________________

$ ________ = $ ____________ x ________
ECS Selected Total CA

(2) Percentage of ECC

Database Confidence Interval

0.2% to 0.4%

Selected % = ____________________

$ _____ = ($) x (÷ 100)
ECS ECC Selected %

d. Solar Energy Studies (SES)

(1) Total Amount

Database Confidence Intervals

$1,675 to $3,253

Selected Total = $ ______________

$ ________ = $ ______________ x ________
SES Selected Total CA

(2) Percentage of ECC

Database Confidence Intervals

0.1% to 0.3%

Selected % = ______________

$ ______ = ($ ECC) x (Selected % ÷ 100)

6. <u>Travel (TR)</u>

$ ________ = ($ ECC) x (________% ÷ 100)

Database: .31% to .48%

Location--Adak: .5% to 1.5%

V. SECTION C (SEC C)

A. Scoping Estimates

1. <u>Regression Model</u>

$ ______ = -719.0 + .0043($ ECC) + 428.8(NDD)
SEC C

2. <u>Percentage of Estimated Construction Cost (APPENDIX I)</u>

		Confidence Interval (%)	
		Lower	Upper
Category Code	______ :	____%	____%
Lead Code	______ :	____%	____%
Work Code	______ :	____%	____%
Database:		0.3%	1.0%

ECC % = __________

$\underline{\qquad\qquad}$ = ($) x (÷ 100)
SEC ECC ECC %

B. Detailed Analysis

1. <u>Shop Drawing--Professional Hours (SDPH)</u>

Hours per Drawing

Database: 2.4 to 2.9

Work Code--Retrofit: 1.0 to 2.0

Computed Average = ____________________

______ = ______________ x ________________
SDPH Computed Average Number of Drawings

2. <u>Shop Drawing--Subprofessional Hours (SDSH)</u>

Hours per Drawing

Database: 1.4 to 1.8

Lead Code--Electrical: .97 to 1.4

--Civil: .8 to 1.6

Computed Average = ____________________

______ = ______________ x ________________
SDSH Computed Average Number of Drawings

3. <u>As-Builts--Professional Hours (ABPH)</u>

Hours per Drawing

Database: 0.9 to 1.1

Lead Code--Structural: 0.9 to 2.6

--Electrical: 0.6 to 0.9

Computed Average = ______________________

________	=	________________	x	________________
ABPH		Computed Average		Number of Drawings

4. <u>As-Builts--Subprofessional Hours (ABSH)</u>

Hours per Drawing

Database: 1.7 to 2.1

Lead Code--Structural: 1.8 to 4.0

Computed Average = ______________________

________	=	________________	x	________________
ABSH		Computed Average		Number of Drawings

APPENDIX L

TEST CASE RESULTS

Test Case No. 1

Project Title: Rehab Consolidated Open Mess

Estimated Construction Cost: $200,000

Location: Adak, Code--1

Date: June 1981

ENR BCI: 327

Category Code: Community Facilities, Code--7

Work Code: Alterations, Modifications, Rehab, Code--3

Lead Discipline Code: Architectural, Code--1

Number of Disciplines: 4

	Government Estimate	Decision Process/ Decision Support	Negotiated Price
Scoping Estimates			
Grand Total Fee	$21,578	$22,615	$25,760
Section A	9,812		$11,803
Regression Model		$11,770	
Cartooning Method		13,716	
% of ECC		10,890	
Section B	$10,191		$12,382
Regression Model		$ 9,148	
% of ECC		8,600	
Section C	$ 1,575		$ 1,575
Regression Model		$ 1,356	
% of ECC		2,200	
Number of Drawing	10		10
Regression Model		12	
ECC/Drawing		8	

	Government Estimate	Decision Process/ Decision Support	Negotiated Price
Professional Design Hours	72		52
Regression Model		145	
ECC/Hour		132	
Detailed Analysis Method			
Section A			
Total Labor Hours	275	410	215
Professional Hours	116	200	96
Sub-Professional Hours	159	210	119
Design Hours	192	301	132
Design Support Hours	83	78	83
Professional Design Hours	72	132	52
Sub-Professional Design Hours	120	169	80
Section A Total	$9,812	$12,000*	$11,803
Section B			
Field Investigation			
Days	10	8	12
Cost/Day	$352	$508	$440
Total	$3,520	$5,064	$5,280
Reproduction	$1,601	$950	$820
Travel	$2,570	$2,000	$2,800

*Actual total was $15,783 but the 6% limitation capped the Section A total at $12,000.

	Government Estimate	Decision Process/ Decision Support	Negotiated Price
Section B Total	$10,191*	$10,514*	$12,382*
Section C			
Shop Drawing			
Pro Hours	20	26	20
As-Builts			
Pro Hours	6	10	6
Sub-Hours	14	19	14
Section C Total	$1,575	$1,453	$1,575
Grand Total Fee	$21,578	$23,967	$25,760

*Total includes some items of "other special cost" not separately shown.

Test Case No. 2

Project Title: Repairs to Roads

Estimated Construction Cost: $637,000

Location: San Diego, Code--5

Date: July 1981

ENR BCI: 327

Category Code: Ground Structures, Code--9

Work Code: Repair, Code--2

Lead Discipline Code: Civil, Code--6

Number of Disciplines: 2

	Government Estimate	Decision Process/ Decision Support	Negotiated Total
Scoping Estimates			
Grand Total Fee	$45,264	$37,893	$52,582
Section A	$23,628		$30,991
Regression Model		$26,590	
Cartooning Method		27,265	
% of ECC		33,251	
Section B	$20,096		$20,008
Regression Model		$ 9,484	
% of ECC		28,665	
Section C	$1,540		$1,583
Regression Model		$2,878	
% of ECC		5,096	
Number of Drawings	13		18
Regression Model		14	
ECC/Drawing		19	
Professional Design Hours	320		326
Regression Model		386	
ECC/Hour		374	

	Government Estimate	Decision Process/ Decision Support	Negotiated Price
Detailed Analysis Method			
Section A			
Total Labor Hours	990	901	1,066
Professional Hours	440	459	446
Sub-Professional Hours	550	442	620
Design Hours	840	662	866
Design Support Hours	150	238	200
Professional Design Hours	320	306	326
Sub-Professional Design Hours	520	357	540
Section A Total	$23,628	$26,245	$30,991
Section B			
Sub-Surface Inv.	$ 3,263	$3,060	$ 3,285
Topographic Survey	13,875	8,500	$12,720
Field Investigation			
Days	6	11	9
Cost/Day	$246	$292	$299
Total	$1,476	$3,212	$2,691
Reproduction	$1,042	$1,258	$1,072
Travel	$240	$2,516	$240
Section B Total	$20,096*	$18,546	$20,008

*Total includes some items of "other special cost" not separately shown.

	Government Estimate	Decision Process/ Decision Support	Negotiated Price
Section C			
Shop Drawing			
Pro Hours	20	45	16
Sub Hours	10	20	8
As-Builts			
Pro Hours	10	17	8
Sub Hours	25	32	16
Section C Total	$1,540	$3,640	$1,583
Grand Total Fee	$45,264	$48,431	$52,582

Test Case No. 3

Project Title: Applied Instruction Building

Estimated Construction Code: $280,000

Location: San Diego, Code--5

Date: May 1981

ENR BCI: 326

Category Code: Operational & Training, Code--1

Work Code: New Construction, Code--1

Lead Discipline Code: Architect, Code--2

Number of Disciplines: 7

	Government Estimate	Decision Process/ Decision Support	Negotiated Total
Scoping Estimates			
Grand Total Fee	$31,676	$38,828	$26,143
Section A	$16,799		$16,775
Regression Model		$20,503	
Cartooning Method		23,490	
% of ECC		15,204	
Section B	$12,380		$7,168
Regression Model		$15,411	
% of ECC		10,080	
Section C	$2,497		$2,200
Regression Model		$3,487	
% of ECC		$2,520	
Number of Drawings	12		22
Regression Model		20	
ECC/Drawing		9	
Professional Design Hours	216		175
Regression Model		225	
ECC/Hour		174	

	Government Estimate	Decision Process/ Decision Support	Negotiated Total
Detailed Analysis Method			
Section A			
Total Design Hours	657	914	645
Professional Hours	296	476	249
Sub-Professional Hours	361	438	396
Design Hours	540	704	551
Design Support Hours	117	210	94
Professional Design Hours	216	326	175
Sub-Professional Design Hours	324	378	376
Section A Total	$16,799	$16,800*	$16,775
Section B			
Sub-Surface Inv.	$3,360	$3,697	Not Included
Topographic Survey	$1,676	$3,855	Not Included
Field Investigation			
Days	5	5	9
Cost/Day	$280	$292	$264
Total	$1,400	$1,460	$2,376
Reproduction	$944	$1,095	$1,292
Other Special Cost			
PED	$3,500	$2,568	$2,000
Solar	1,500	1,610	1,500

*Actual total was $25,091, but the 6% limitation capped the Section A total at $16,800.

	Government Estimate	Decision Process/ Decision Support	Negotiated Total
Section B Total	$12,380	$6,733*	$7,168
Section C			
Shop Drawings			
Pro Hours	14	39	40
Sub Hours	68	24	10
As-Builts			
Pro Hours	6	15	-
Sub Hours	18	29	30
Section C Total	$2,497	$3,113	$2,200
Grand Total Fee	$31,676	$26,646	$26,143

*Subsurface Investigation and Topographic Survey not included in total.

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